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Kentucky Geological Survey

Bulletin No. 9.

FLUORSPAR DEPOSITS
OF KENTUCKY.

1907.



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MINES SHOWN BY NUMBERS ON MAP.

CRITTENDEN COUNTY MINES:

- | | | |
|-----------------------------|------------------------------|----------------------------|
| 1. Ada Florence Mine. | 19. Givens Mines. | 37. Old Dad Mine and Mill. |
| 2. Alice Mine. | 20. Glendale Mine. | 38. Old Glory Mines. |
| 3. Asbridge Mines. | 21. Hodge Mines. | 39. Old Jim Mines. |
| 4. Beard Mine. | 22. Holly Mines. | 40. Parish Mine. |
| 5. Ben Belt Mine. | 23. Keyes Mine. | 41. Pogue Mine. |
| 6. Big Four Mine. | 24. Keystone Mine. | 42. Redd Mine. |
| 7. Brown Mines. | 25. Lady Farmer Mines. | 43. Red Hill Mine. |
| 8. Clement Mine. | 26. LaRue Mines. | 44. Reiter Mine. |
| 9. Columbia Mines and Mill. | 27. Leander Mine. | 45. Riley Mine. |
| 10. Commodore Mine. | 28. Leona Mine. | 46. Stevens Tunnels. |
| 11. Cox Mines. | 29. Lucile Mines. | 47. Struck-it-Rich Mines. |
| 12. Crosson Mines. | 30. Lucky Star Mines. | 48. Tabb Mines. |
| 13. Dan Riley Mine. | 31. Miller Mine. | 49. Tabor Mines. |
| 14. Deer Creek Mine. | 32. Mann Mine. | 50. Thurman Mine. |
| 15. Eaton Mine. | 33. Mathews Mine. | 51. Wheatcroft Mines. |
| 16. Ebbie Hodge Mine. | 34. Memphis Mines. | 52. Wilson Mines. |
| 17. Eclipse Mine. | 35. Meyers. | 53. Yandell Mines. |
| 18. Edwards Mine. | 36. Nine Acre Mine and Mill. | |

LIVINGSTON COUNTY MINES.

- | | | |
|---------------------------------|--------------------------------|-----------------------|
| 54. Ramon Babb Mine. | 59. Hudson Mine. | 64. Tom Spees Mine. |
| 55. Bonanza Mine. | 60. McDowell Mine. | 65. St. John Mines. |
| 56. Burns Mine. | 61. Morning Star Mine. | 66. Henry Woods Mine. |
| 57. Evening Star Mine and Mill. | 62. Nancy Hanks Mine and Mill. | |
| 58. Aus Guill Mine. | 63. Royal Mine. | |

CALDWELL COUNTY MINES.

- | | | |
|-------------------|--------------------|-----------------|
| 67. Bright Mine. | 70. Marble Mines. | 73. Stone Mine. |
| 68. Dodds Mines. | 71. Ray Mines. | 74. Tyrie Mine. |
| 69. Lowery Mines. | 72. Senator Mines. | |

CHRISTIAN COUNTY PROSPECTS.

- | | | |
|---------------------------|--|--------------------------|
| 75. Ellis Prospect. | 78. Head's Victoria Mine (Prospect).
2½ miles s. e. of Pod. | 80. Jarvin Prospect. |
| 76. Freeman Shaft. | 79. Hord Prospect. | 81. McReynolds Prospect. |
| 77. Fruit Calc. Prospect. | | 82. Williams Prospect. |

LYON COUNTY PROSPECTS.

- | | | |
|-------------------------------|------------------------------|--------------------------|
| 83. Cook Calc. Prospect. | 85. Padon Prospect. | 87. Smith Prospect. |
| 84. Eddyville Calc. Prospect. | 86. Redd Manganese Prospect. | 88. Wadlington Prospect. |

TRIGG COUNTY PROSPECTS.

- | | | |
|------------------------|----------------------|--------------------|
| 89. Cooper Prospect. | 93. Malone Prospect. | 97. Peel Prospect. |
| 90. Hillman Prospect. | 94. O'Hara Shaft. | 98. Pue Prospect. |
| 91. Ferguson Prospect. | 95. Overby Shafts. | 99. Taoler Shafts. |
| 92. Johnson. | 96. Owen Shaft. | |

UNION COUNTY PROSPECT.

100. Taryta Spring Prospect.

OTHER MILLS.

- | | |
|---|--------------------|
| 101. Kentucky Mill is n. of 102 and
marked 100 on map. | 102. Sanders Mill. |
| | 103. Tenme Mill. |







NANCY HANKS MILL—ALBANY MINING AND INVESTMENT CO.

Kentucky Geological Survey

CHARLES J. NORWOOD, *Director*

BULLETIN No. 9.

Fluorspar Deposits of Kentucky

WITH
**Notes on the Production, Mining and Technology of the
Mineral in the United States**

ALSO
SOME DATA CONCERNING BARITE DEPOSITS

BY F. JULIUS FOHS

OFFICE OF THE SURVEY: LEXINGTON, KY.

1907

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LETTER OF TRANSMITTAL

His Excellency, J. C. W. BECKHAM,
Governor of Kentucky.

Sir: I have the honor to present for publication Bulletin No. 9, on the Fluorspar Deposits of Kentucky, with data relating to the general occurrence of fluorspar, its technology, etc., by Mr. F. Julius Fohs.

It is believed that this Bulletin will be accepted as the most complete publication on Fluorspar that has ever been issued. By liberal use of Dr. Beck's "The Nature of Ore Deposits," Mr. Fohs has been enabled to compile an extended list of occurrences of fluorspar in association with various type groups of certain minerals. While it may be admitted that in many instances the occurrences noted are of interest rather to the student of mineral associations (and of much use to him) than to the seeker after economic deposits of fluorite, it is believed that the list will nevertheless prove serviceable to a large number of readers, and that it is properly included in what was intended to be a comprehensive account of the mineral. The chapter devoted to analytical methods will certainly be welcomed by those who have to do with the technical applications of fluorspar. The chapter on the uses of the mineral will, it is believed, prove quite helpful. And just here it may be well to note, in addition to what has been said by Mr. Fohs in regard to the uses of the spar, that fluorspar is used in Russia in the manufacture of a new building material, to which the name "kremnitz" has been given. According to the Mining Magazine (August and December, 1905), "kremnitz" is composed of sand, clay and fluorite, subjected to a high temperature and molded into any form desired. It "can be colored to imitate the most precious marbles."

Necessarily, this Bulletin deals chiefly with the deposits in the western end of the State, in what is known as the Ken-

tucky-Illinois District, of which by far the larger part is in Kentucky. As a matter of record, it may be well to say that the late Dr. Joseph G. Norwood was probably the first geologist to recognize the really important character of the Illinois deposits; that the fact that the Kentucky deposits occur in true veins associated with deep faults was first noted by the writer, in 1875; and that the sheeting of the rocks was first suggested by Emmons and subsequently verified by Smith and Ulrich.

The fluorspar deposits of Central Kentucky have received less attention from prospectors than it is possible they may deserve. In fact, it seems not improbable that systematic explorations of those rocks that lie below the Lexington—either as they come to the surface here and there, or as they may be reached underground—will develop fluorspar deposits of importance. In the further study of the barytes deposits of that part of the State, particular attention will be paid to this question.

In chapter I., Mr. Fohs calls attention to the effect of foreign competition in the home market for American spar. Fluorspar enters the American market duty free, and it is partly in consequence of that fact (to which is to be added alleged discriminations in freight charges from the seaboard) that English competition seriously affects the American miners. This matter deserves investigation. Fluorspar mining is an instance of one really “infant industry” which might be helped by an import duty.

Very respectfully,

C. J. NORWOOD,

State Geologist.

May 1, 1907.

CHAPTER I.

PRODUCTION OF FLUORSPAR.

The Western Kentucky District has become, since 1896, one of the largest producers in the world. Its yearly production for the past ten years was greater than that of any American district, except in 1906 when Southern Illinois somewhat surpassed it, and greater than that of any foreign country save Germany and Great Britain, the last having exceeded it only since 1905. Caldwell, Crittenden and Livingston were the producing counties, but by far the major part has been produced by Crittenden county. Fluorspar has been found also in the adjoining counties, Christian, Lyon and Trigg, but as yet has not been produced in quantity from them.

The Southern Illinois district, comprising Pope and Hardin counties, is its largest American competitor. The Central Tennessee district, comprising Smith, Trousdale and Wilson counties, and the Colorado districts in Boulder and Custer counties, are small producers, the latter supplying part of the Colorado demand. The Castle Dome district in Yuma county, Arizona, from 1902 to 1904, was also a small producer, supplying part of the Western demand.

The first fluorspar shipments from an American mine, so far as it is possible to determine, were made from this district in 1871. The River Valley Mining Co., operating the Royal mines, made some small shipments that year. This company erected the first mill here, for grinding fluorspar, it being of the ordinary grist mill type. For No. 1 ground spar they received \$60 per ton and for No. 2 they received \$30, at glass works in Baltimore. Although they had a fair demand for both lump and ground at high prices, owing to financial difficulties the company was compelled to suspend. About the same time some fluorspar was mined at the Yandell mines,

though none was shipped till 1878, when they were operated by Henry Glass. The first fluorspar shipments were made in the early seventies from the Rosiclare mines.

The Dycusburg Lead Mining Co., Cincinnati Lead & Spar Mining Co., and the Walton Spar Mining Co., made fluorspar shipments from 1882 to 1886, the amount of which is unknown. The fluorspar was mined at the Yandell, Memphis and Beard mines. Some 1,500 tons were shipped in 1886, according to Mineral Resources for that year.

About 1893, J. W. Waggoner is said to have come into the district and begun mining fluorspar from shallow pits, shipping both in bulk and barrels.

Porter and Hudson began really the first active shipments in 1896, and the Kentucky Lead & Fluorspar Co., which they formed in 1897, continued to make shipments. They erected a sort of flouring mill at Memphis mines for grinding No. 1 fluorspar. No figures are available for these years and merely estimates have been given in the table.

The Fluorspar Co. succeeded Mr. Waggoner in 1898 and made small shipments that year. This and the Kentucky Fluorspar Co. of Tennessee (successor to the Kentucky Lead & Fluorspar Co.) were the only American shippers, the latter shipping considerably the most.

The same companies were among the shippers in 1899, though two new companies were added to the list. The National Lead, Zinc & Fluorspar Co. made their first shipments of fluorspar—No. 2 brown lump—from the Marble mine, and the Eagle Fluorspar Co. shipped all grades from the Hudson, Babb, Guill and Evening Star mines. The Kentucky Fluorspar Co. remained the largest producer; during the year it discontinued the Memphis Mill and erected the Kentucky Mill just above the depot at Marion, since which time it has ranked among the three largest American producers of ground fluorspar. The same year the Eagle Fluorspar Co. erected a mill for the concentration of lead, zinc and fluorspar, and in addition installed an improved fluorspar grinding plant, shipping several hundred tons of ground fluorspar that year. Owing to their desire to concentrate their efforts on the separation problem, the grinding plant was not used after that year.

In 1900, the same companies made shipments. The Fluorspar Co. was reorganized in February of that year, and during 1900 and 1901 its shipments amounted to nearly one-fourth of the total for the district. The Kentucky Fluorspar Co. shipped about 60 per cent. of the output for 1900.

The Chicago Mining Co. made small shipments for the first time in 1901, the Kentucky Fluorspar Co., The Fluorspar Co., and the Eagle Fluorspar Co. being the other shippers. The quantity shipped ranked, beginning with the first, in the order named.

February, 1902, witnessed the consolidation of The Fluorspar Co. and the Kentucky Fluorspar Co. of Tennessee as the Kentucky Fluorspar Co., a Kentucky corporation, which shipped the bulk of the product in 1902. Companies making small shipments that year were the Eagle Fluorspar Co., the Lucile Mining Co. (successor to the Chicago Mining Co.) and the National. The Pittsburg Mining and Reduction Co. erected a small grinding plant at the Pittsburg mines, but this was not a success, as their fluorspar contained too much calcite. The Marion Mineral Co. began the production and sale of unwashed gravel fluorspar in the latter part of the year. This year witnessed great activity throughout the district, and the shipments were greater than in any year preceding 1905. The U. S. Geological Survey, in co-operation with the Curator of the State Geological Department, made a preliminary investigation of the resources of the district in 1902.

In 1903, we find the Kentucky Fluorspar Co., The Marion Zinc Co., the Marion Mineral Co. and the Pittsburg Mining & Reduction Co. paying freight tariffs, in amounts ranking in the order named; all except the first in amounts on less than twelve hundred tons. This year fell but little behind 1902.

The year 1904 was more apathetic than either of the two preceding years. The Kentucky Fluorspar Company continued considerably the largest producer, with the Marion Mineral Co. second. The remaining three shippers were the Pittsburg Mining & Reduction Co., the Marion Zinc Co., and Roberts & Co., the latter the only new company, all in quantities less than 500 tons. The falling off in shipments as compared with 1902 and 1903 was due to two causes: First, the condition the mines had been put in by not doing sufficient dead work

ahead to develop new bodies of fluorspar along the veins, thus requiring this work to be done with a less output of fluorspar. Second, the market for flux was not as steady, due to depression of iron and steel industries.

Statistics of Production.

In Table I, is given the fluorspar output of the principal producing countries in metric tons.* This shows the United States and Germany to stand neck and neck for first place with Great Britain lagging but little behind. France and Spain each have small productions.

TABLE I.
FLUORSPAR OUTPUT OF THE PRINCIPAL PRODUCING COUNTRIES.*
(In Metric Tons.)

Year.	France.	Germany	Spain.	United Kingdom.	United States.
1896	1,940	21,603	3	400	5,442
1897	2,722	23,232	2	302	3,973
1898	3,077	23,787	5	57	11,021
1899	5,140	24,306	310	796	21,506
1900	3,430	30,310	4	1,471	19,646
1901	3,970	28,741	Nil	4,232	17,763
1902	2,650	14,177½	93	6,388	47,190
1903	2,447	13,028½	4,000	12,102	33,577
1904	2,047	13,540½	(+)	13,160	33,069
1905	(+)	15,019½	(+)	39,466	35,299
1906	.	.	.	36,280	28,655

*Mineral Industry, Vol. XIV., p. 129, with corrections and additions that are to appear in Vol. XV.

‡Exports: German statistics no longer report production of Fluorspar.

†Not reported.

‡Not yet published.

*A metric ton contains 2204.6 lbs. avordupois, and is equal to 1.1023 tons of 2000 lbs.—C. J. N.

Fluorspar shipments previous to 1896 are here presented:

TABLE II.

PRODUCTION OF FLUORSPAR IN THE UNITED STATES 1882-1895*.

(In Short Tons.)

Year.	Quantity.	Value.	Average value per ton.	Year.	Quantity.	Value.	Average value per ton.
1882	4,000	\$20,000	\$5.00	1889	9,500	\$45,835	\$4.82
1883	4,000	20,000	5.00	1890	8,250	55,328	6.71
1884	4,000	20,000	5.00	1891	10,044	78,330	7.80
1885	5,000	22,500	4.50	1892	12,250	89,000	7.26
1886	5,000	22,000	4.40	1893	12,400	84,000	6.77
1887	5,000	20,000	4.00	1894	7,500	47,500	6.33
1888	6,000	30,000	5.00	1895	4,000	24,000	6.00

*From Mineral Resources, U. S. Geological Survey.

Table III., now presented, was made up largely from Mineral Resources, the annual statistical publication of the U. S. Geological Survey. The only other statistics we have for comparison are those of The Mineral Industry, annually published by the Engineering and Mining Journal. Previous to 1898, the two show only small differences. During the years 1898, 1899, and 1900, the latter reports a far larger production than the former, due to the fact that one of the Kentucky producers gave in much exaggerated figures. Since 1900 the figures in the latest Mineral Industry are those of the U. S. Geological Survey, except 1905.

TABLE III.

FLUORSPAR PRODUCTION IN THE UNITED STATES, 1896-1905.*

(In Short Tons.)

Year	United States		Illinois Dis- trict.	Tennessee & Arizona Dis- tricts.	West Ken- tucky District.	Crude	Ground
	Quantity	Value					
1896	6,500	\$52,000	5,000	.....	1,500	.....	.....
1897	5,062	37,159	2,500	.....	2,562	.....	.....
1898	7,675	63,050	.....	.....	7,675	.....	.....
1899	15,900	96,650	8,400+	.....	12,500+	12 400	8,500
1900	18,450	94,500	8,450+	.....	15,000+	15,450	8,000
1901	19,586	113,803	6,086	.....	13,500+	15,886	3,700
1902	48,018	271,882	18,360	628	23,030	43,310§	4,708
1903	42,523	213,617	11,418	275	30,885	36,888++	5,235
1904	36,452	234,755	17,205	151	19,096	21,081§§	15,421
1905	57,385(1)	362,488	83,275(2)	1,376 (3)	22,694 (4)	49,852(5)	7,538

*Compiled from Mineral Resources, U. S. Geological Survey, except when marked.

†Approximate.

‡Actual shipments.

§Includes 800 tons held in stock.

||Includes 6,550 tons held in stock.

§§Includes 4,671 tons held in stock.

(1) Excess of actual production, see "Comments on the Output."

(2) Over twice the actual production, Kentucky really having the largest production.

(3) Colorado and Tennessee.

(4) Slightly too high.

(5) Includes 2,437 tons held in stock.

The figures given by Mineral Resources for the years 1902, 1903 and 1904 (also 1905, see Table III) are excessive, as will be seen by comparison of Tables III. and IV. The figures of the latter were compiled by the writer from the most authoritative sources accessible.* Placing the excess production of 1903, 1904 and 1905 at 2,000 tons each year, which was certainly not exceeded, and we still have an excess of 10,000 to 12,000 tons to be accounted for. These discrepancies in the U. S. Geological Survey figures are probably due to: (1) Receipt of padded returns from some of the opera-

*For details refer to Production of Lead, Zinc and Fluorspar of Western Kentucky, by F. Julius Fohs, Chap. V., State Mine Inspector's Rept., 1903-1904, pp. 62-76

tors. (2) Unintentional duplication of returns by adding to the figures of shipping companies the returns of producing companies who sell their product to the shipping companies; the latter companies always include their purchased product as well as their own. That considerable differences may arise from such duplication may be seen by comparing the number of producers and shippers in Table V. (3) The inclusion of shipments made by operators to their storeyards or between their storeyards.

TABLE IV.

GROUND, LUMP, GRAVEL AND TOTAL SHIPMENTS FROM WESTERN KENTUCKY, 1896-1906.

(In Short Tons.)

Year	Ground*	Lump	Gravel	Totals
1896	†	‡	1,500	1,500††
1897	†	‡	2,562	2,562††
1898	1,000§	‡	4,000	5,000‡‡
1899	1,500§	‡	5,000	6,500§§
1900	1,750**	‡	6,750	8,500§§
1901	2,065**	‡	11,435	13,500§§
1902	2,387**	‡	14,413	16,800** ‡‡
1903**	3,130	3,942	7,458	15,122
1904**	3,421	2,390	7,306	12,978
1905**	5,220	2,470	11,461	19,151
1906**	4,819	904	6,570	11,793

*Production except for 1905 and 1906 which represents shipments.

†Unknown, included with gravel.

‡Included with gravel.

§Estimated.

††Mineral Resources, U. S. Geol. Survey.

‡‡Approximate.

§§Reported, Illinois Central R. R. shipments.

**Statistics compiled by writer.

From Table IV. we also learn the extent of the production of ground fluorspar from Western Kentucky. By comparing with the total ground production given in Table III., we find this district, except in 1899 and 1904, to have produced from more than one-half to more than two-thirds of

this grade. In 1904, according to figures from Mineral Resources, the total ground production was 15,421 tons. Deducting the Kentucky production of 3,421, we have a remainder of 12,000 tons to represent the production of the two Illinois mills, a production exceeding their capacity at that time had they operated continuously by 3,000 tons. Since these companies did not operate their mills more than one-third of the time during the year, as one had a strike on hand and the other was erecting its plant and doing development work, it is unlikely that the Illinois ground production exceeded much if any the Kentucky production of this grade.

In the table following the number of producers is given in the columns marked "Pr.," and number of shippers in the columns marked "Sh."

TABLE V.
NUMBER OF FLUORSPAR PRODUCERS AND SHIPPERS IN THE UNITED STATES, 1902-1906

Districts	1902		1903		1904		1905		1906	
	Pr. (*)	Sh.	Pr. (*)	Sh.	Pr. (*)	Sh.	Pr.	Sh.	Pr.	Sh.
Castle Dome, Arizona	2	2	1	1	1	1				
Central Tennessee	1	1	1	1	1	1	1	1	1	1
Colorado							1	1		1
Southern Illinois	5	4	5	5†	5	4	4	6	6	8
Western Kentucky	10	4	6	5	8	5	12	4	10	6
	18	11	13	12	15	11	18	12	18	16
Less companies shipping from two States				2		2		2	2	2
Totals.....	18	11	13	11	15	9	18	10	16	14

*From Mineral Resources.

†Mineral resources only reported 4. The writer is responsible for the other figures.

GENERAL REVIEW OF PRODUCTION IN 1905 AND 1906.

Western Kentucky and Southern Illinois districts continue in the lead as producers of fluorspar, with Central Tennessee and Colorado districts producing small amounts in 1906.

A larger amount was marketed in 1906 than in 1905, but the amount mined was less, due to conditions in Southern Illinois, where the shipments exceeded production by more than 5,000 tons, part of the shipments having been made from spar in stock. The Kentucky production was so regulated by the producers as to make the production about equal the shipments. For the first time since 1897, the Kentucky production and shipments both fell below those of Illinois. In the production of ground fluorspar, however, the Kentucky district continues to hold first place. In Kentucky, among the shafts that have not been regular producers heretofore there are no less than five that are now in such a state of development as to be capable of supplying, in 1907, an output greater than the total Kentucky production in 1906; while all the old mines, with one exception, are capable of turning out a greater production than at any time in the past. The Kentucky mines, indeed, are in position to supply any demand that may be made upon them in 1907.

Tonnage Marketed, Values, Etc.

The fluorspar marketed from American mines in 1906 amounted to 37,034 short tons, valued at \$211,231. This is an increase of 872 tons over 1905, but the value of the 1905 product was about equal to that of the 1906. Of the 1906 product, 8,314 tons, valued at \$82,576, were ground; 6,097 tons, valued at \$34,398, were in lump form; while of gravel there were 22,623 tons, valued at \$94,257. The following table gives the status of the industry, as to certain details, for 1905 and 1906:

TABLE VI.

COMPARISON OF STATUS OF FLUORSPAR INDUSTRY IN 1905 AND IN 1906.

(In short tons.)

District	Mined	Ground Marketed.	Lump Marketed.	Gravel Marketed.	Total Marketed. *	In Stock Dec. 31st.	Companies		
							Developing Not Marketing	Mining	Marketing
1905.									
Colorado & Tennessee ..	1,756	.....	1,676	.....	1,676	80	0	2	2
Southern Illinois	16,602†	2,313	3,816	9,206	15,335	6,762‡	4	4	6
Western Kentucky	20,560	5,220	2,470	11,461	19,151	10,583	2	12	4
Total	38,918	7,533	7,962	20,667	36,162	17,425	6	18	10‡
1906.									
Colorado & Tennessee ..	620	.....	660	.....	660	40	1	2	2
Southern Illinois	19,532	3,995	4,533	16,053	24,581	2,975	4	6	8
Western Kentucky	11,440	4,319	904	6,570	11,793	10,455	3	10	6
Total	31,592	8,314	6,097	22,623	37,034	13,470	8	18	14‡
Increase in 1906		781	.....	1,956	872	.....	2	0	4
Decrease in 1906	7,326	.....	1,865	.....	.....	3,955	.....	.....	.....

*"Total marketed" represents : gravel shipped, of which less than half was mined as gravel; the remainder having been mined as lump and crushed, while all the ground was mined as lump.

†Based partly on returns and partly on shipments.

‡The apparent error in total is not real, since companies shipping from two States were deducted.

Comments on the Output, Etc.

The Illinois operators undoubtedly supplied excessive returns to both the U. S. Geological Survey and the Engineering and Mining Journal for 1905, since they showed production and shipments double the real ones for that year. The statistics given by the U. S. Geological Survey for Kentucky were also excessive by a few thousand tons. Those reported for Kentucky by the writer in The Mineral Industry for 1905 were, on the other hand, under the actual total by a few hundred tons. A comparison of the large overestimated returns of Illinois producers with the prac-

tically correct ones for Kentucky producers was entirely unjust to the latter. The hurtful effect lay both in giving the Illinois district the name of yielding the largest supply, and in leaving the impression that in 1905 there was a considerable overproduction in the United States, which did not and does not now obtain. In 1905 Kentucky actually exceeded the Illinois shipments by nearly 5,000 tons.*

It was because of this state of affairs that special efforts were made to obtain for this Bulletin a correct statement of the shipments of 1905, and the returns presented in the foregoing table resulted.

The figures for shipments for 1906 result from returns of the transportation companies, carefully checked with those reported by the operators. It is gratifying to note that they tallied closely in the aggregate.

The reason Kentucky shipments dropped to second place may be summed up as follows:

1. Advantage of \$1.00 per ton in freight rates, given Illinois. In addition rebates also are reported as being given to Illinois shippers.

2. Illinois operators having cut prices in order to compete with the English, and also to undersell Kentucky operators.

3. The further invasion of the English shippers into the Western and Southern trade, previously largely controlled by Kentucky shippers.

4. The invasion of Illinois operators, for the first time, into Southern trade.

5. The partial retirement from the market of one of the large shipping companies, owing to caving of one of their Kentucky mines; hence inability to produce.

The Western Kentucky district has exported ground fluorspar both to Canada and Mexico, while crude fluorspar is also shipped the former. German consumers have sought quotations on Kentucky fluorspar in quantity, although in excess of 15,000 tons of fluorspar were exported by Germany in 1905, largely to Austria-Hungary and nearby countries.

*The U. S. Geological Survey reports for 1906 a production of 40,796 short tons, valued at \$244,023, or \$5.98 per ton. According to the writer's figures, such tonnage and value are too high, the former being too high by fully 9,000 tons.

COMPANIES PRODUCING AND SELLING**FLUORSPAR.**

The following companies were producing and selling fluorspar from Kentucky in 1905. Those marked with a star (*) sold to the consumer; the others to local companies: Big Four Mining Co., Drescher & Co., Givens Mining Co., Great Northern Mining & Milling Company, Kentucky & Indiana Mining Company, *Kentucky Fluorspar Co., Keystone Lead & Zinc Co., Keystone Mineral & Mining Co., Louisville-Marion Mining Co., *Marion Mineral Co., *Marion Zinc Co., and Wheatecroft Mineral Co. *Roberts & Co., made sales only. The Albany Mining & Investment Co. and the Senator Mining Co. produced but did not sell any of their product.

The companies producing and shipping fluorspar from Kentucky in 1906 (those which shipped to consumers being marked with a star) were as follows: *Albany Mining & Investment Co., Bluegrass Fluorspar Co., *Cumberland River Mining Co., Drescher & Co., Edwards Mining Co., Great Northern Mining & Milling Co., Kentucky & Indiana Mining Co., *Kentucky Fluorspar Co., *Marion Zinc Co., and J. M. Persons; *Marion Mineral Co., and *Geo. P. Roberts & Co., were shippers but not producers. Besides these, there were numerous others developing properties which did not ship or sell fluorspar during the year. Among these were the Eagle Fluorspar Co. and the Keystone Mineral & Mining Co. The list of shipping companies does not include ten or more agents who sell fluorspar for the above companies.

The producing and shipping companies in Illinois in 1906 were: *Crystal Fluorspar Mining Co., *Compton Mining & Smelting Co., *Cave-in-Rock Mining Co., *Evansville Lead & Spar Co., *Fairview Fluorspar and Lead Co., *Rosiclare Lead & Spar Mines, and the *Pierce Fluorspar Co. The *Basic Chemical Co., *Geo. P. Roberts & Co., and *Ma-

Mon Mineral Co. were shippers but not producers; while the Hamp Fluorspar & Lead Co., the Geo. W. Robinson Spar. Lead & Zinc Co., and James Henry, were producers who made no sales in 1906.

*D. C. Roberts & Co. was the Tennessee producer and shipper in 1906; while *R. W. Blackett reported shipments from his property at Silver Cliff, Colorado. In Central Kentucky the Monitor Mineral Co., of Mercer county, is the only company developing fluorspar properties. No shipments were reported by that company.

GRADES OF FLUORSPAR.

Fluorspar is classed as lump, gravel and ground. Lump and gravel, spoken of together as crude fluorspar, may be had in three grades according to quality. Ground is to be had in four grades, but these are not correlative with the grades of crude fluorspar. In the term "gravel" it is now the usage to include both the gravel resulting from disintegration of lump through natural causes, and the crushed product of the mills. Gravel may be had washed or unwashed, although natural gravel alone may be had unwashed.

No. 1 fluorspar is usually white, less often slightly colored and should run 96 per cent. or more calcium fluoride, the remainder consisting of silica, iron oxides, alumina, calcium and magnesium carbonates, alkalies, hydrocarbons and moisture. Dark colored fluorspar, especially if somewhat shattered and iron stained, is not classed as No. 1, owing to the larger amount of silica it contains, such silica being deposited between the cracks in the weathering process. Colored fluorspar not so affected, if clear and highly crystallized, is not objectionable in this grade. Dark brown and purple black are not included in this grade at all, since they are usually charged with heavier and a larger amount of hydrocarbons.

American ground fluorspar all falls in the No. 1 grade, but is itself graded into three grades, namely, Extra No. 1,

No. 1 and No. 2. A still lower grade of ground is obtainable in England, which is treated of under No. 3 fluorspar. No. 1 ground will run 98 per cent. or over calcium fluoride and about 1 per cent. silica. This grade is generally used where ground is called for. Extra No. 1 contains less than 1 per cent. total impurities, with very little silica, bringing several dollars more per ton than No. 1. This grade is produced from hand selected white lump fluorspar. While the bulk of that purchased by acid manufacturers is No. 1 (owing to the lower price), nearly all of Extra No. 1 also goes to such manufacturers. No. 2 ground will run from 96 to 98 per cent. calcium fluoride with up to 2 per cent. silica. This grade is of a darker color than No. 1, the off color being due to the darker colored fluorspar employed, as well as to a small amount of lead, an impurity pleasing to some glass makers. This grade is employed for cheaper wares by both the glass and enamel people. The bulk of the ground fluorspar demand is for No. 1 ground. Ground fluorspar is used, also, where a specially pure flux is needed. American ground averages 85 mesh in fineness.

No. 2 fluorspar will run 90 per cent. or over calcium fluoride with less than 4 per cent. silica, the remaining impurities consisting largely of calcite and sometimes limestone. Colored fluorspar, excepting unwashed red gravel, nearly all falls into this grade. The crushed product of the mills belongs to this grade. Some of the lump of this grade will go 95 per cent. calcium fluoride, when it may be classed as Extra No. 2. This grade is largely used for fluxing purposes.

No. 3 fluorspar includes, according to present usage, all fluorspar running between 60 and 90 per cent. calcium fluoride. Unwashed gravel belongs to this grade, as does fluorspar associated with a considerable amount of calcite, limestone, quartzite, barite, etc., also mill tailings. This grade is used as a flux in iron smelting, and especially where low priced fluxes are necessary. A grade of English ground may be classed as No. 3 ground. This corresponds in quality with the best of No. 3 fluorspar, running, it is reported, about 88 per cent. calcium fluoride.

The writer would suggest that the fluorspar classed now

as No. 3 be divided into two grades, to be designated No. 3 and No. 4; No. 3 to include fluorspar running from 80 to 90 per cent. This grade would embrace most unwashed and not too dirty gravel; also lump fluorspar associated with not exceeding 12 per cent. silica in the form of quartzite, sand or chert, and from 8 to 15 per cent. calcite, limestone, etc. No. 4 would include all fluorspar containing 60 to 90 per cent. calcium fluoride, its silica content not to exceed 15 per cent., with the remainder made up largely of limestone, calcite, etc.; this grade would embrace the mill tailings and fluorspar largely associated with quartzite or limestone. Of what is classed here as No. 4, the demand is very limited. This grade would also embrace the artificial fluorspar by-product of cryolite.

SELLING PRICES.

Prices received for American fluorspar at mine shipping points are regulated by the quotations at Pittsburg, the Pittsburg quotations being partly controlled by the prices of imported English fluorspar. Quotations in New York are about \$1.00 more than at Pittsburg to offset difference in freight rates. For several years the English importations have practically controlled American prices. In 1906, however, American shippers entered into active competition with the English, making inroads into English trade in the East, where the English had previously nearly everything their own way. In retaliation the English sold fluorspar further West and in the South. This accounts for the slight decrease in the average price of the lower grades of American fluorspar in 1906, lower prices having been made for such grades in the disputed territory.

The ruling prices for fluorspar have remained practically constant for several years past. Occasionally a new company has offered fluorspar at a lower price and caused temporary flurries in the market, but such were only for some particular grade and left no permanent effect.

Table VII shows the highest, average and lowest prices obtaining f. o. b. cars mine shipping point, compiled from the Mineral Resources of the U. S. Geological Survey, for the years 1896 to 1905, inclusive. The averages reported for 1905 having been based upon exaggerated returns are all somewhat too high, while the extremes obtaining were in part both higher and lower than those reported for that year.

TABLE VII.
PRICES OF FLUORSPAR, 1896 TO 1905.
(Per Short Ton.)

Year	Average Crude	Average Ground	Total Average	Crude Lowest	Crude Highest	Ground Lowest	Ground Highest
1896	.....	.....	\$3.00	.....	.....	.....	.....
1897	.....	.....	7.34	.....	.....	.....	.....
1898	.....	.....	8.21	.....	.....	.....	.....
1899	\$5.62	\$7.15	6.08	.....	.....	.....	.....
1900	5.02	5.66	5.12	.....	.....	.....	.....
1901	5.02	9.22	5.81	.....	.....	.....	.....
1902	5.19	9.98	5.66	\$2.85	\$11.50	.....	.....
1903	4.28	9.99	5.02	3.00	11.50	.....	.....
1904	4.97	8.44	6.44	3.60	11.50	\$ 8.00	\$10.00
1905	5.33	11.00	6.32	4.00	8.00	10.00	12.00

The prices per short ton for 1906, reported received by American marketing companies for fluorspar in car load lots of 15 tons or more, were: Ground, \$8.90 to \$15.00; lump, \$3.85 to \$8.70; and gravel, \$2.50 to \$6.00.

Fluorspar for foundry purposes was retailed in quantities from 50 pounds to ton lots, usually barreled: Crude from \$10 to \$20 per ton; ground, \$20 to \$32 per ton. The smaller glass and enamel companies also purchase, at times, in small lots of from 1-2 to 5 tons. One company reported the sale of a ton of specimen fluorite at \$60.

The fluorspar from Colorado and Tennessee belongs to the lump class and the prices received were in the limits for that class in Kentucky and Illinois, although the average price received in the two former were higher than that re-

ceived in the two latter districts. This was due to the higher quality of that sold from Tennessee and the proximity to market of the Colorado product. The differences in price between American grades No. 1, 2 and 3 crude, and also between the different grades of ground, vary from 50 cents to \$3.00 per ton.

Fluorspar of similar grade costs from 50 cents to \$1.50 more in lump form than as gravel, partly because of the higher cost of producing lump, and partly owing to the less silica content, since it is capable of closer control in grading than gravel.

The average prices received for American fluorspar, per short ton, in 1906, were: Ground, \$9.93; lump, \$5.64; and gravel, \$4.16. The average price of all grades was \$5.70.

Mining companies that do not market their own product sell the same to marketing companies at prices just sufficiently less than the prices above given to pay the marketing companies for handling such product.

Fluorspar, except ground and small lots of lump and gravel which are barreled or sacked, is usually shipped in bulk in closed cars. Owing to car shortage in the latter half of 1906, a small amount was necessarily shipped in coal cars. Boated fluorspar is usually barreled, except for barges, upon which it is shipped either in cars or loose in the barge. Barging between local points costs as much as 50 cents per ton, and in some instances more, exclusive of cost of loading. Freight rates vary according to distances and quantity, from \$2.00 to \$20.00 per ton, the latter price obtaining for small lots to distant points.

COMPETITION WITH AMERICAN FLUORSPAR.

The sources of competition are three in number: (1) Limestone flux, (2) imported fluorspar and (3) cryolite and cryolite products.

As to Limestone Flux.—A little more than 50 per cent. by weight per ton of pig iron produced is the amount of limestone flux at present consumed. During 1905 it has been estimated that 13,220,000 tons of limestone were used for flux in the iron and steel industry, while 357,000 and 521,000 tons respectively were used in lead and copper smelting. For the former the cost of limestone flux is 45 cents, while for copper and lead it is 90 cents per ton. While in present practice it would not be practicable to substitute fluorspar entirely for limestone as a flux, yet in many cases this can be done to advantage, while in practically all other cases it can be used in connection with limestone to much better advantage than the limestone alone, at equal or less cost. One part of fluorspar is said to go as far for fluxing purposes in practice as ten parts of limestone. The cost of fluorspar in 1906 did not exceed more than eight times the cost of limestone flux for iron and steel nor more than four times that for lead and copper. A steady increase is notable for several years past in the use of fluorspar as against limestone flux so that at present the amount consumed in smelting is one-half of one per cent. of the amount of limestone flux used. There is no reason why the percentage should not greatly increase when it becomes better known that fluorspar is much the more powerful flux, reduces fuel consumption, increases percentage of metal obtained, and acts as a detergent, yielding metal of better quality; in addition, it means the handling of several million tons less of raw material, thus reducing the amount of storage space and labor required.

Lead ore containing 5 to 10 per cent. fluorspar shipped from the Kentucky-Illinois district is not assessed a penalty, for the fluorspar is distinctly an advantage to the smelter as a flux. In copper smelting it is also an advantage.

As to Imported Fluorspar.—The imported English fluorspar has been a source of competition of considerable importance for several years. As the Treasury Department keeps no record of such imports we do not know their amount though they probably reach 30,000 short tons. The low price demanded for English fluorspar is due to: (1) The low cost of securing the product from the old dumps of the Derbyshire lead mines; (2) the low cost of mining the gravel by means of steam shovel in large open pits; (3) the low cost of ocean steamer freights, the product coming over as ballast in the holds of vessels, at a cost, it is said, of \$1.75, and costing but 75 cents additional to bring it from the mines to the ocean port, making a total freight cost of \$2.50 to land it at American ports; (4) the low freight tariffs granted the product from seaboard as far west as Pittsburg, the published rate for which is \$2.60, while it is said that through rebate, the cost to English shippers has only been \$1.60 per ton; (5) the admittance of fluorspar duty free at American ports. During 1906, as already pointed out, American producers entered into active competition with the English, and the fight will be on in earnest it is said in 1907. While the English product has been much inferior to the American, it is reported that a better grade is now being supplied than formerly.

In Great Britain, fluorspar is reported mined in only two counties, Derby and Durham, the former having twelve mines owned by six different operators and producing about seven-eighths of the total product; the latter having seven mines owned by three different operators which produced the remaining one-eighth. The total number of fluorspar mining concerns is nine. The production of fluorspar in 1904 was 18,160 metric tons, (20,018 short tons), having a value of \$75,054; while in 1905 it was 39,446 metric tons, (43,481 short tons), valued at \$88,030. The amount mined from open cuts or quarries was less than 4 per cent. in 1906, while in 1905 it was about 7 per cent. The output for 1906 is reported as being 36,280 metric tons, equal to 39,991 short tons.

As to Cryolite.—Cryolite has been used for the manufacture of hydrofluoric acid and opaque and opalescent glass, in which uses it is almost entirely now superseded by fluor-

spar. Cryolite has also been largely used in the manufacture of aluminum, a practice now becoming obsolete for these reasons: Impure cryolite costs about three times as much as fluorspar and beauxite which may be used in its stead and which are capable of yielding three times as much aluminum, making the ratio of economic value, allowing for returns from by-products of the cryolite, of cryolite to fluorspar and beauxite nearly 1 to 5.

The imports for cryolite for the years ending Dec. 31, 1904, and 1905, were 959 long tons valued at \$13,708, and 1,600 tons valued at \$22,482 tons respectively, while for the year ending June 30, 1906, there were 1,644 tons valued at \$24,972. The imports for the years 1897 to 1903, inclusive, varied from 5,383 to 10,115 tons from whence it may be seen that in the last three years there has been a considerable decrease in importation. The figures indicate the importation in 1905 and 1906 to be about the same, though the cost increased being \$14.05 in 1905 and \$15.19 in 1906.

American fluorspar can be used for all purposes, at less cost and with as good or better results, to which cryolite is put, except the manufacture of sodium salts for which the bulk of that imported is now used. As a result, cryolite and its 60 per cent. by-product of calcium fluoride (each ton of cryolite used in the production of sodium salts yields about a ton of this), are but a small source of competition.

OTHER VEIN STUFFS IN WESTERN KENTUCKY.

Lead and Zinc Ores.

The first lead smelter was erected in the district about 1870 by the River Valley Mining Company, at the Royal Mine, for smelting the lead ore and recovering the silver content, which was exceedingly small; but it did not attain much success. A few runs were made, and the lead on hand smelted and shipped, but, when the company became involved in financial difficulties, work was discontinued.

Between 1874 and 1877, lead was shipped from the Columbia mines by Page & Krausse, who had erected a concentrating plant and a small Scotch hearth smelter. The pig lead was hauled twelve miles by wagon to the Ohio river. The lead sulphide was associated with zinc carbonate, and was secured at the 50 foot level from the Eureka vein, which showed four feet of the rich ore. Because of the difficulties encountered in mining, due largely to excessive water, and to difficulties between the partners as to plans, and to the decline of lead from 5 to 2½ cents, the work was discontinued.

While no figures are available, the shipments of lead ore from this district previous to 1880 must have amounted to at least 1,000 tons.

In 1901, a small amount was shipped from the Morning Star mine, while in 1902, the National Lead, Zinc & Fluorspar Company made small shipments of lead concentrates from the National Mill at the Marble mines.

The Columbia Mining Company and the Kentucky Fluorspar Company made small shipments from the Columbia and Kentucky mills, respectively, both in 1903 and 1904.

There was shipped 144,518 lbs. of galena in 1905, an increase of 21,982 lbs. over 1904. The small shipments were produced as a by-product by the Kentucky Fluorspar Company, Drescher and Company, and Blue & Nunn.

An increase of 37,325 lbs. is to be noted for 1906, over 1905, the shipments in 1906 amounting to 181,843 lbs. The shipping companies were: Kentucky Fluorspar Co., Sanders Ore Separating Co., and the Marion Zinc Co. The Southern Illinois lead shipments and production were considerably in excess of those of Western Kentucky both in 1905 and 1906.

In 1906 Illinois lead concentrates shipments amounted to 430.4 tons with a reported silver content of from 3½ to 11 oz. per ton. The reported estimated amount of lead or ore on hand ready for shipment from Illinois mines at the end of 1906 was 170 tons.

While zinc had been discovered as early as 1835 in Western Kentucky, no deposits were worked to recover zinc till in May, 1901, when Blue & Nunn made their first shipments of zinc carbonate from the "Old Jim" mine. Thousands of tons, largely carbonate, some sulphide, were mined from an

open cut, the mineral being gotten practically from the surface to a depth of forty feet, on either side of an igneous dike, the deposit in places exceeding 50 feet in width. The ore was hand cleaned; the pea ore product washed with log washer, and the sand ore cleaned on two Overstrom tables. The largest shipments of zinc ore from the district were made in 1902, the product being all from this mine.

Small shipments of sulphide were made by the Western Kentucky Mining Company from the Lanham shaft of the Columbia mines, in 1901. Their successors, The Columbia Mining Company, made no shipments in 1902, when they erected the Columbia mill for concentrating lead and zinc, from which they shipped several carloads of zinc, both in 1903 and 1904.

The Mann zinc mine was discovered in 1901, and the Marion Zinc Company made small shipments from both the Mann and McDowell mines, which adjoin, in 1902, and, while they have been operated some since, owing to litigation in connection with the Mann mine no further shipments have been made. The Old Dad mine was opened in 1903, and shipments of zinc carbonate were made from it in 1903 and 1904. This was in part hand-cleaned, and in part washed with log washers. The Henderson Company also made small shipments in 1903, from their Lady Farmer mine which adjoins the Old Jim, which received treatment similar to the latter, making shipments also in 1904. Blue & Nunn made some shipments in 1904 from the Nine Acre mine. Part of this ore was hand-picked, part hand-jigged, and part put through the Columbia mill. A number of deposits were somewhat exploited in these years, from which no shipments were made, owing to lack of milling facilities.

Only 403.8 short tons of zinc ore were shipped in 1905, of which 126 tons were sulphide and 277.8 tons were carbonate. These shipments showed a decrease of 555 tons from that of 1904. The decrease is attributable to the fact that the Old Jim mine was idle during the year, except for a little development work, this mine having previously supplied the bulk of carbonate and part of the sulphide ore.

The Old Dad mine was the largest zinc mine producer during 1905, but, because of a large amount of development

work in progress, the production was small. The fact that some of the more important zinc mines were idle, or only a little development work was being done at them, also accounts for the decrease in tonnage.

Among those who made small shipments of zinc ore in 1905, were, Blue & Nunn, Watkins & Drescher, The Henderson Company, and the Marion Mineral Company. A small amount was produced which was not put on the market.

In 1906, the zinc production was even less than in 1905. Although some new carbonate deposits were opened, little of such carbonate was shipped. (See finds at Old Jim Sinkholes and Lady Farmer, under "Progress in 1906.") The Old Dad was able to get out scarcely any ore owing to caving of the 60-foot open cut, which had to be re-caught before further extraction of ore was feasible. The Old Jim mill was re-erected at this mine and some nice concentrates from zinc dirt obtained. There was a small shipment from the Hodge open cut as well as from the Old Jim. In the matter of sulphides, the first shipments of zinc separated from fluorspar-zinc ores are to be recorded, a distinct advance, auguring well for increased shipments in 1907. These were from the Sanders mill, discussed on a subsequent page. As a result, two companies have been organized to re-open the Columbia and Nine Acres mines, and a mill is to be erected equipped with Sanders separators at the latter. Other developments tending to increase the zinc production are to be looked for, and altogether the outlook is bright.

The total zinc ore shipments from the district to date are:

	Short Tons.
Zinc sulphide or sphalerite	1,164
Zinc carbonate or smithsonite	8,958
Total zinc ore	<u>10,122</u>

In the same period, the shipments of zinc ore from Southern Illinois were comparatively small. In 1903 or 1904, the first small carbonate shipments were made from the Empire mine. No carbonate was shipped in 1905, but in 1906 four companies made shipments aggregating 103 tons, and in ad-

dition a small amount remains unshipped. No sulphide shipments other than small lots to be used in separating tests have yet been made.

Shipments of lead and zinc ores from Western Kentucky by years are shown in the following table:

WESTERN KENTUCKY LEAD AND ZINC SHIPMENTS, 1901—1906
IN POUNDS.

Year.	Galena.	Zinc Sulphide.	Zinc Carbonate.
1901	-----	50,000	3,154,000
1902	-----	116,000	7,462,100
1903	83,152	1,300,000	3,155,800
1904	122,536	506,800	1,410,800
1905	144,518	252,000	555,600
1906	181,843	103,400	176,600

The work of the State Geological Survey has demonstrated the probability of finding zinc deposits along the most sheeted portions of the master faults and such parts of them where the fluorite pinches; also along sheeted zones parallel, to or complementary of the master faults. In general, where the master fault carries the most zinc the complementary will carry a larger amount of fluorspar and vice versa. Also, that the chance of finding zinc carbonate resulting from the erosion of limestones having sheeted zones is good, and further development along these lines is advisable, that is, more surface cross cutting in the red clay residual from the decomposition of limestone walls of master faults should be made for distances up to 200 feet or more from such faults.

Barite.

Barite (barytes, barium sulphate) was first shipped from the district in 1903, when the Marion Zinc Co. shipped several carloads from their Ray and Lowery mines, 2 miles east of Fredonia, in Caldwell county. No work of consequence was done at these mines in 1904 or 1905. In 1906, further open-cutting was done and a log washer for cleaning the barite was installed. A small tonnage was reported shipped, while they have several hundred tons of off color gravel yet to be cleaned for shipment. The hacked lump product of

these mines is high grade. It is reported that the company intends to erect a mill for bleaching and grinding barite at an early date.

In 1905, a new deposit of barite of considerable size was found on the property of the Kentucky Fluorspar Co. at the Commercial shaft on the Tabb lode, where the vein appears over 20 feet in width.

Some of the barite of the Western Kentucky district is of the best grade, while a part of it has its value reduced by a small amount of fluorspar occurring intergrown with it. In general the barite in the smaller veins that show little or no faulting, with limestone for one or both walls, shows where fluorspar is at all associated a large per cent. of the latter while that of the larger faults shows only fluorspar in small amount associated.

The production of barite in the United States for 1904 was 65,727 short tons, valued at \$174,958, while in 1905 it was 48,235 tons valued at \$148,803. The average price per ton was \$2.66 and \$3.08 for 1904 and 1905 respectively.

Calcite.

A small tonnage of calcite was reported as shipped for fluxing purposes by the Schoolfield-Spees Mining & Milling Co., from the Tom Spees mine both in 1905 and 1906. These were the first calcite shipments from this district. The product was barreled and was shipped by the Ohio.

Calcite occurs in narrow veins alone or as bands of the master faults lining the limestone walls from 3 to 12 feet in width. It is also found along the faults cutting out ore or fluorspar at times. As the calcite deposits are of very considerable purity, usually gray or white in color, there is no reason why those nearest transportation should not be exploited and the product put on the market, there being an increasing demand for this product. It is used for fluxing purposes, for purification of wood alcohol, for Portland cements, for lime, for certain chemical compounds, etc.

Firesand or Fireclay.

The only shipments of this product have been made by the Western Clay and Mining Co., from their Steven's Tun-

nels, 12 miles southwest of Marion. The shipments from 1903 to 1906 aggregate 6,163 short tons. No shipments were made in 1905 and the shipments in 1906 were small. The products contain 91 to 93 per cent. silica (in part, perhaps, colloidal), 2 to 3 per cent. of alumina, 0.5 to 1.5 per cent. of iron oxides, the remainder consisting of calcium and magnesium carbonates and alkalies. It is procured from between walls of a large fault, one wall of which is Chester quartzite, and the other St. Louis limestone, the width of the deposit reaching 35 feet in places; the deposit is proven to a depth of 120 feet and for nearly 400 feet in length. It results from the disintegration of the quartzite, and in part from that of the cherts, the disintegration having partly resulted from frictional brecciation, in part from chemical decomposition.

Several other deposits of similar character have been developed. Two in Crittenden, at the Anderson Jones and Mayflower (Jim Croft) shafts, while another was reported opened at the Bush prospect on the John Franklin place adjoining the Jones; all of these are 9 to 10 miles west of Marion. One was opened in Livingston county on the Angling place, several miles east of Smithland.

Deposits similar in composition but of entirely different origin have been worked by the Western Clay and Mining Co. at Smithland, and considerable shipments made; such are, however, not included in the above aggregate.

Fluxing Clay.—Small shipments were made in 1906 for the first time from Kentucky of the red clay such as occurs in connection with the zinc veins at the Old Jim mine, and is also found with fluorspar veins where the limestone walls decay and red clay results. Shipments were made by Blue & Nunn. The product is used in connection with fluorspar, etc., for fluxing, the aluminate of iron it contains being used to reduce the fusing point as does thermit. Shipments, small in quantity were also made from Illinois mines of this product.

OTHER VEIN STUFFS IN CENTRAL KENTUCKY.

Barite, Lead and Zinc Developments in 1905 and 1906.

Data in regard to fluorspar in the Central Kentucky District are given in Chapter II. During the last two years, especially in 1906, a number of companies have been developing prospects on the barite, lead and zinc veins of the district—some of the prospects showing excellent mineral—and several have been mining for the market. Shipments of barite and galena have been made; also of refined (precipitated) barium sulphate (blanc fix), with by-products of sodium sulphide and lead fume. Efforts were made to collect statistics of production but without avail, since few of the companies were willing to furnish the necessary data. To those gentlemen who did respond to requests for information, the sincere thanks of the Survey are tendered. It is hoped that with another year all companies will agree to furnish statistics.

Up to the end of 1906, the Mutual Mining Co., of Scott county, was the only manufacturer of barite products. The Ohio Lead Mining Co. and the Lead Mining Corporation of America, of Owen County, the Union Mining Co., of Henry county, and the Jessamine Barytes Co., of Jessamine county, also have mills. Of the four, only the Union Mining Co. turned out any lead concentrates during the last two years. The first three have operated chiefly for lead. The Jessamine mill has only recently been completed; it will turn out crushed and ground barite, and is provided with bleaching vats. The Clinch Valley Barytes Co. expects to begin operations near Lancaster, Garrard county, at an early date. Some shipments of crude barite have been sent to Virginia from Garrard county. In Anderson county, the Barium Mining Co. was preparing to develop barite deposits during 1907. In Bourbon, the Kentucky Mining and Developing Co. began operations near Millersburg. The outlook for a large output of barite and associated minerals from the Central Kentucky District is promising.

Following is a list of companies that are or have been operating in the district, together with some of the known prospects:

Anderson county.—Barium Mining Co., Lawrenceburg, R. F. D. No. 3. Head office, 51 Perrin Building, Cincinnati, Ohio. W. D. Beggs and Thos. Jouvett.

Bourbon county.—Kentucky Mining and Development Co., Millersburg. General office, 519 Madison Avenue, Covington, Ky. Lead and barite.

The Clay prospects, on lands of Hon. Cassius M. Clay, near Paris. Barite, galena, sphalerite. In Bulletin No. 2, Prof. Miller reports twenty veins on Mr. Clay's lands. Several shallow prospect shafts have been sunk on the veins.

Daniel Isrigg prospect, Paris. Two shafts were sunk on the vein, one of them to a depth of about 100 feet, but no mining has been done within recent time. Barite, galena and sphalerite.

Clark county.—(See Fayette county.)

Fayette county.—Dolan prospect, on land of Joseph F. Dolan, about seven miles northwest of Lexington. Barite with sphalerite.

Morton's Mill prospects, two veins. The most important one crosses Boone's creek, about a mile above the mill, into Clark county. Two prospect shafts have been sunk on the latter, one in Fayette and one in Clark, the latter being about 100 feet deep. Fluorite, calcite and barite, with traces of sphalerite.

Potter's Field prospects, on the old Potter's Field property and exposed in cuts of the Belt Line and Lexington & Eastern railroad, Lexington. Barite.

Russell's Cave prospect, about seven miles northeast of Lexington. Some years ago a shaft about 200 feet deep was sunk on the vein, the object being to mine for lead alone. Barite with some galena.

Franklin county.—Judge W. S. Pryor, Frank K. Kavanaugh, and others, of Frankfort, have opened prospects on Flat creek, about a mile from the Kentucky river. Some small shipments were made for testing purposes. Barite, zinc and some galena.

Camp Pleasant Mining Co., Stamping Ground, R. F. D. No. 2. Home office, Hillsboro, Mo. Thos. J. Jett, President;

W. W. Jones, Superintendent; F. H. Brown, Secretary. Barite, galena and zinc.

Garrard county.—Clinch Valley Barytes Co., Lancaster, Ky., and Honaker, Va. Chiefly barite.

Dix River Mining Co., Stanford. Chiefly barite and zinc.

Harrison county.—Lair prospects, on L. & N. railroad, three miles southeast of Cynthiana. Some prospecting was done on the vein, barite with some galena, some years ago. No mining has been done in recent time.

Hoggin prospects, on L. & N. railroad, one mile south of Lair. A small amount of prospecting has been done. Barite with galena showing in streaks.

Henry county.—Boston & Kentucky Mining Co., Lockport, A. E. Place, Secretary. Lead and barite.

Lockport Mining Co., Lockport. Lead and barite.

Union Mining Co., Lockport. General office, Madison, Indiana. Lead and barite.

Jessamine county.—Jessamine Barytes Co., Nicholasville. Chiefly barite. This company is acquiring barite holdings in other counties.

There are a number of prospects in this county, but it is not known at the moment who the holders now are.

Mercer county.—Monitor (formerly Quinn) Mining Co. The company owns or controls several veins, including fluorite, calcite and barite deposits. Its Twin Chimneys and Fantail mines have been referred to in the account of fluorspar mines. Its great Green Million calcite vein, so far as it has been tested, shows very pure calcite with no metallic minerals to affect its quality.

Owen county.—Lead Mining Corporation of America, Hoosier mine, Moxley. Barite with considerable galena. It is understood that this company has made no output during the last two years. The plant includes crusher and concentrating tables.

Ohio Lead Mining Co., Gratz mine, Gratz. General office, Portsmouth, Ohio. Lead and barite.

Twin Creek Mining and Smelting Co., Cantor mine. Chiefly zinc and calcite. P. O., Owenton, care of Hon. J. W. Cammack. There was no output during the last two years.

Scott county.—Mutual Mining Co., Stamping Ground. W. S. Kissinger, Manager. The company controls several barite

veins carrying galena and zinc, in both Scott and Franklin counties.

Woodford county.—A number of veins occur in this county, the best known, which have been prospected to some extent, being the following: The Faircloth, of fluorite; the Shryock Ferry, of barite with some calcite and blende in its upper extension, changing to calcite (chiefly) with some blende below; the Shropshire, of barite with some sphalerite; the Prewitt, of barite, with a little galena and blende and some fluorite; and the Withrow, of barite with galena.

(It should be understood that the foregoing list does not by any means purport to be a complete catalogue of the barite and fluorspar occurrences in Central Kentucky. The list is given merely as indicative of what may be expected from the district. It is intended that a complete examination of the district shall be made by Mr. Fohs during the season of 1907, and a special Bulletin will be issued on the barite deposits of the State.—C. J. N.)

CHAPTER II.

THE FLOURSPAR INDUSTRY IN 1905 AND 1906.

Progress of the Fluorspar Industry in 1905.

Practically all the mines at work in 1904 were operating in 1905, with a number of new ones. Quite a number of new deposits were encountered in the exploitation of the old mines, and in this respect the year showed a marked advance. A number of new mills were erected, and the condition of the industry generally was favorable.

Western Kentucky District.—The widest vein mined in this district during 1905 was 36 feet of gravel fluorspar, at the 145-foot level of the Pogue mine. The widest lump vein was 16 feet at the John mine. At the Mary Belle mine two new veins were encountered, and one of the shafts showed 15 feet of fluorspar with galena associated.

Among the new producers was the Kentucky mine, which has a 12 to 20-foot vein of gravel fluorspar in the upper levels, and 10 feet of lump in the lower one. This mine, together with the Matthews with which it is connected, produced a good tonnage during the year.

The New Memphis incline gave up to 12 feet of No. 1 lump at a depth of 75 feet, while the old Memphis continued to turn out a large amount of No. 1 fluorspar.

The Keystone mine, with a good vein up to 12 feet wide, carrying some galena; the Wheatercroft, and a new shaft on the Tabb land, may be mentioned among others as having large veins producing in 1905, while the veins of 6 feet or less were numerous. Among new deposits may be mentioned those opened on the Ben Belt, Brown, Cox, Senator and Par-

ish properties. The last named is a large flat deposit about fifty feet thick, replacing limestone near a fault.

Among developments of special interest in the matters of lead and zinc, are the finding of a 3-foot vein of almost solid galena (a small per cent. of fluorspar only being associated) at one of the shafts of the Mary Belle mine; also of a good vein of zinc ore, carbonate in the upper part and coarse grained sphalerite below water level, associated with a little fluorite and calcite, at the Eclipse mine (formerly the McMi-can prospects); of an 8-foot sheeted zone of lead and zinc sulphides, with a little fluorspar and calcite associated, at the John mine about 50 feet east of the main fault at the 247-foot level. The Hodge zinc shaft was cleaned out and some work done; here the zinc occurs in quantity, replacing oolite.

One new deposit of barite of considerable size was found. This at the Commercial shaft on the Tabb fault zone, where the vein appears over 20 feet in width. Calcite was mined at the Spees mine in Livingston county, from a secondary replacement zone, of the Jamieson fault zone.

Detail surveys, which the writer had in charge, were executed by the Kentucky Geological Survey during the year, and a deal of new and valuable data relative to the deposits and industry have been brought to light and will be published at an early date by the Survey.

Two preliminary railroad surveys were executed with a view of putting a belt road into the mining field.

Milling in the Western Kentucky District.—So far as the writer is aware, no fluorspar milling is being done except in the Western Kentucky and Illinois districts. Some lump was shipped in previous years, to be ground elsewhere, but now the ground product is largely shipped direct to the consumer. The year has certainly seen the largest tonnage of ground fluorspar both produced and shipped, ever known. That shipped from one mill in Western Kentucky exceeded the total output for the previous year.

No changes are to be noted for the Kentucky mill. The Nancy Hanks mill, erected by the Albany Mining and Investment Company, has just been completed. It is situated at their Nancy Hanks mine, near Salem, Ky. This mill, like

most of the others of this district, follows somewhat the Joplin pattern, but differs in the installation of a rather complete sizing system, using a new type of shaking screens, the Ratcliffe-Cohenour patent, and a separate four-cell jig for each size. The problem is to concentrate the fluorspar and galena.

The erection was begun of a new grinding plant at the John mine, about eight miles southwest of Salem, Ky., in 1905, but, owing to the burning of the mine and mining plant, and the necessity of first putting it again in shape, it was not completed in 1906, though it is reported that the Cumberland River Mining Company intend to complete it early in 1907.

The new Eagle mill, near Salem, was practically completed this year, and the building for the Sanders mill is about ready for the installation of machinery. The aim of these mills is the separation of the sphalerite (blende) from the fluorite so as to produce a commercial zinc ore, and at the same time save the associated galena. The former is a dry concentration plant, using Hooper Pneumatic tables, and a very complete sizing system.

The National Mill was not in operation during the year. The Seacoast Mill at Paducah, using Krom tables, was not successful in handling Kentucky-Illinois district mixed ores, and was removed to Madison, Indiana, the early part of the year, where it will be used on the galena-barite ores of Central Kentucky, of which it makes a fair concentration.

Southern Illinois District.—The Fairview mine was sufficiently developed by the early part of 1905 to make it capable of turning out 50 tons daily, this in operating its 211 and 270-foot levels, and giving it the record for daily production. An idea may be obtained of the large amount of fluorspar this mine is capable of producing since it maintained a width of six to thirty feet for over 500 feet without showing any evidence of decrease. The product shows no change in the lower level. A sufficient amount of galena is secured with the fluorspar to more than pay the running expenses of the mine and mill.

The Rosiclare output was about 25 tons daily while running, secured from the 300-foot level, where the vein shows no change in character beyond the usual pinches and swells.

At the Black mine near Bay City, where a number of small veins had been previously opened, a 12-foot vein, carrying fluorspar and galena, was encountered, placing it in the list of producers for 1905. Some shipments were made from the Lee Mine. Here there is an exceptionally wide vein of gravel fluorspar.

Milling in Illinois.—The Fairview mill was remodeled in the early part of the year and the capacity increased. Cooley jigs and a Wilfley table were installed to replace the jigs of the Hartz pattern. The lead concentrates of the plant are considerably cleaner than those made previously, but the fluorspar product is not improved, and No. 2 product is turned out, crushed in two sizes. At the time of the writer's visit the daily capacity of the mill for concentration of fluorspar and galena was said to be about forty tons, while the grinding division handled about 100 barrels per day. The capacity, however is being increased.

No changes were made at the Rosiclare mill. The Compton Mining & Milling Company started the erection of a mill of the Joplin type at their Mary mine, for separating fluorspar, lead and quartzite.

Central Kentucky District.—The Monitor (formerly Chinn) Mineral Company continues development work in Mercer county, at the Twin Chimneys mine, some work also being done at the Fantail mine. At the former, the shaft is being deepened; at the latter, a crosscut tunnel is being driven; the vein consists principally of fluorite. At the Twin Chimneys the vein averages about four feet. It is banded for the most part symmetrically, fluorite, barite, and calcite occurring in separate bands, varying from an inch to a foot in width. While barite forms only a very small part of this vein at this mine, there are many veins in this district that consist chiefly of barite, some of which will be operated the coming year. The shaft at the Twin Chimneys has been sunk deeper since the writer's visit, as Prof. Norwood, who recently examined the mine, says they are now 225 feet deep (80 feet below the adit) and the vein in the bottom is five feet in width, largely fluorite with but little barite, with the walls of Campnelson ("Chazy" of Linney) limestone. Some

of the veins of this section have been briefly noted in Bulletin No. 2 of the Survey.*

Milling in Central Kentucky.—A mill for the separation and grinding of fluorspar, barite and calcite is promised for the Central Kentucky District. According to information given by the engineer in charge, the Monitor Mineral Company has let a contract for the mill, the work to begin on it in February. Its equipment is to consist of a picking table, two crushers of the Blake type, three sets of Cornish rolls, two four-cell differential jigs, sizing screens, accessory elevators and conveyors, a Ford concentrating table, one rotary dryer, one Griffin mill (with provision for two) to grind the fluorspar, and eight buhr mills of Virginia buhr-stone for grinding the calcite and barite. An additional section of the plant is to be constructed to manufacture barium salts. Later, the calcite, in part, is to be utilized in the manufacture of hydrated lime and sand-lime brick at the mine.†

Central Tennessee District.§—Two properties were operated in the latter part of the year. The Foley mine is situated about eight miles west of Carthage, in Smith county. Here, near the surface, massive crystalline fluorspar occurs in boulders weighing from 10 to 1,500 pounds in a limey clay. In sinking the shaft 25 feet of limestone were encountered, immediately below which is an eight-foot vein of fluorspar dipping 10 to 12 degrees west and striking northwest. Crystallized calcite, very similar in appearance to the fluorspar, lines the foot wall which consists of a gray lime-sand or clay resulting from the disintegration of the limestone. The fluorspar is said to average 98 per cent. calcium fluoride. This may be a blanket vein originally replacing limestone, similar to those in the Western Kentucky and Southern Illinois districts, occurring in close proximity to a vertical vein.

The Alcorn property, about eighty miles east of Nashville, on the Tennessee Central, was also being developed. Here yellow, crystallized fluorspar occurs, covering the

*Miller, A. M., The Lead and Zinc Bearing Rocks of Central Kentucky. *Bulletin No. 2, Kentucky Geological Survey*, 1905.

†Statement given the Director of the Survey by the engineer in charge.

§Private Communication, D. C. Roberts.

ground within a foot or two of the surface. Some thirty tons have been mined from surface picking. Sinking has failed to locate the vein, though fluorspar is found to fill the limestone crevices 8 to 10 feet below the surface.

Similar fluorite is reported from the vicinity of Nashville.

Colorado District.—Fluorspar was mined and shipped for the first time in Colorado, at Jamestown, Boulder county, in 1905. It was obtained from strong veins in Algonkian crystallines associated with andesite intrusions of later date. Open cut methods were employed.*

Castle Dome District, Arizona.—This district, while on the list of producers, has not made any shipments for the last two years.† It is reported that there are thousands of tons of crude fluorspar on the dumps. It is secured here as a by-product from the mine, as is necessary to facilitate the mining.

That previously shipped from this district, it appears, was largely used in the manufacture of Portland cement by California plants. According to information received from Mr. E. C. Eckel, its use for such purpose has been discontinued. The lack of demand for the Arizona product may thus be accounted for, there being at present no other industries in the immediate section for which it is used.

Progress of the Fluorspar Industry in 1906.

The year 1906 found the same districts producing fluorspar as in 1905, except in Colorado, where the Silver Cliff district became a producer and the Boulder district left the list. Many new developments, both in mining and milling, are to be recorded.

*Hovey, E. O., Fluorspar and Cryolite. Extract from Mineral Resources, United States Geological Survey, 1906, p. 4.

†Private communication from Robt. D. Luce, Superintendent Castle Dome Mining & Milling Company.

Western Kentucky District.—The Kentucky Fluorspar Company, with mines in Crittenden county, has to its credit the largest amount of development work.

In a new shaft at the Brown mines, a vein more than 4 feet thick of fluorspar and zinc carbonate was secured. At the Hodge mines, exploitation work on all three veins was in progress, and a large central power plant is shortly to be erected. The Meeks Incline, on the most southerly vein, has six feet of white fluorspar and galena of the beautiful ribbon structure type. On the main Hodge, work was done in the Air Shaft; zinc carbonate was mined from surface cuts, and a considerable body of gravel fluorspar was mined at the Reed cut. On the Jones vein, at the Holly mines, 4 feet of fluorspar were cut in the main shaft. Gravel was mined on contract on the Redd and Klondike veins. A new vein, strike N. 25 degrees E., of purple fluorspar was discovered 50 yards southwest of the Klondike vein. The Memphis Incline showed an ore shoot 14 feet wide, largely No. 1 fluorspar. A neat plant has been installed, and with aid of hammer drills, the fluorspar is being mined at one-half its former cost. The present output will be increased upon the opening of new levels, sinking for which is now in progress.

From maps and sections prepared by Mr. C. S. Nunn, the president, (see accompanying plate), it is evident the Memphis ore shoots pitch to the right, looking down the dip, agreeing with Clayton's law.* They pitch 28 to 30 degrees from the horizontal, and this pitch corresponds with the direction of secondary slickensiding in the fluorspar, while the slickensiding of the walls dipped about 87 degrees. The amount of displacement of the Memphis fault is $70\frac{1}{2}$ feet. The larger ore shoots (3 feet and over) of which there are two, vary from 30 to 90 feet in length and are 120 feet apart. Bordering these are narrow sections merging into barren sections (20 to 45 feet long) beyond, while half-way between the large shoots is a narrow shoot.

At the John and Nancy Hanks mines the ore shoots also pitch to the right, while at the Nine Acres, they pitch to the left.

*Clayton's law is, briefly, that "ore shoots pitch to the right as seen when looking down a lode along its dip." Its general application is questioned, but when found applicable to a district it is of great assistance in exploiting the local ore deposits.—C. J. N.

Immense gravel shoots on either side of the Kentucky mine were stoped; to the south, the Milliken shaft was sunk almost entirely in gravel, getting white lump on one side. In sinking on the Yandell incline, nice white fluorspar was encountered at 115 feet depth.

The main fault was cut at Glendale, showing at this and the Leona mine 10 to 16 feet of galena-charged fluorspar. New openings were made by the Blue Grass Fluorspar Company on the Tabor and Asbridge, and small power plants were installed. The vein in these at 80 feet varies from 4 to 12 feet gravel and lump, showing locally a deal of galena. At the Wheatercroft, a secondary vein of purple fluorspar was cut.

On the Columbia fault zone, a 3-foot vein of zinc carbonate was secured on the Wilson land; while at the Ada Florence, at 132 feet, a good vein of fluorspar-galena was found near the shaft, which, a short distance southwest, changed to zinc sulphide and galena with only 2 per cent. fluorspar. A compressor, etc., were installed here. Arrangements are being consummated for reopening the Columbia mine under new management. Developments were in progress on the Memphis fault zone; also at the Edwards, Thurman and Eclipse. The latter has 2½ feet of jack, and is equipped with a small air plant. Fluorspar 2 to 4 feet wide was cut in contact with a mica-peridotite dike at the Will La Rue prospect. Veins of fluorspar, showing well in lead, are reported opened at the J. O. Belt and Ed Flanary. At the Riley, several levels were operated, and sinking continued below 200 feet. New shafts are being sunk at the Parish and Leander. At the Silver Star, a 3½ foot fluorspar vein was cut. A new vein of zinc carbonate was discovered at the Old Jim Sinkholes, while both carbonate and sulphide were secured at the Lady Farmer. Carbonate was mined at the Old Dad, and considerable 8 per cent. zinc dirt secured at the Red Hill.

In Livingston county, at the Evening Star mine, a body of ore 12 feet wide was cut at 120 feet, carrying 20 per cent. sphalerite, 5 per cent. galena, and the remainder chiefly fluorspar. The mine is now capable of an output of 50 tons per day. At the Nancy Hanks, to the south on same fault zone, a large output of fluorspar and lead was had from the

168 and 180-foot levels. A lump fluorspar shoot, 18 feet wide, was mined at the John mine; and, considering that the mine and plant had to be entirely rebuilt, having burned, the output was unusually large.

No mining was done in Lyon, Caldwell or Trigg counties, though operations in the last two will resume in the spring. Lead and fluorspar were discovered for the first time in Christian county, at the McReynolds' prospect, giving renewed impetus, and Eastern capitalists are preparing for considerable work in 1907. Further work was also done at the Freeman prospect.

The party headed by the writer completed geologic mapping and investigations of the lead, zinc and spar deposits of the six counties of the district. The conclusion reached concerning these deposits are, briefly: The fluorspar supply is practically inexhaustible; zinc ore occurs in more considerable quantity than previously supposed, and the assured solution of the milling problem should greatly increase its production; lead occurs in sufficient quantity with both the fluorspar and the zinc deposits to make a nice profit above what is secured from either type of deposit alone; large pure calcspar deposits occur which will repay mining; favorable conditions occur in parts of northern Christian, northern Lyon, northern Trigg and eastern Crittenden counties, thus extending the eastern, southeastern and southern limits of the district; chances for economic deposits appear less in the faults near the borders than those near center of field; chances along undeveloped portions of the main faults and their complementary fractures, especially in the limestone but also in the quartzite walls, are good and more cross-cutting is advisable. One of the results of the work was the discovery of a simple method of determining the probable strikes of cross and intersecting complementary fractures, where the strike of one fault is known. Recent development work showed highly favorable results, many good ore shoots being found on old properties, both along the strike and in depth, along the faults.

Topographic mapping was done by the State Geological Survey and U. S. Geological Survey acting in co-operation in Caldwell and Crittenden counties. A re-survey for a railroad route was made by private parties in the western part of the field.

Milling in Western Kentucky District.—The Kentucky mill continues a large ground fluorspar producer, and the only change made was the installation of an eighty-horse-power Corliss engine to secure more adequate power. The Riley mill was operated but little. The Nancy Hanks became a regular producer and a large tube mill was added to increase grinding capacity; the newly patented Ratcliffe-Cohenour shaking screen is in successful operation here. The Old Dad zinc mill cleaned some carbonate.

In Caldwell county, the Union Central Mining Co. erected the Union mill, a mill of the Joplin type, at the Stone mine, for the separation of fluorspar and galena, but it will not be operated till in the spring of 1907.

The Eagle Fluorspar Co. continued experimental work on zinc-fluorspar ores at their Evening Star mill throughout the year.

A successful separation of fluorspar and zinc sulphides is at last being accomplished, and by at least two distinct processes. One of these, which is already in operation in the district, is a non-acid flotation process; the other is electrical, represented by two distinct types of electrical separators, tests with which are reported as satisfactory. The processes are described on succeeding pages.

Southern Illinois District.—The Rosiclare mine, which is 325 feet deep, has been worked for 900 feet at the 300-foot level, the vein varying from 3 to 28 feet of fluorspar and galena. A secondary, striking N. 17 degrees E., intersecting the main vein not far from the shaft, was also worked. The Fairview Incline, more than 330 feet deep, was worked at four levels and for about 625 feet, has been completely stoped out to the 300-foot level; in the latter, the vein was from 6 to 14 feet wide.

On Lead Hill, three mines, the Evansville, Robinson, and Cave-in-Rock, worked two veins, bedded by replacement, 1 foot to 12 feet thick, fluorspar, galena and zinc carbonate. Both beds were worked by entries at the Robinson; while at the Evansville, where they were 150 feet into the hill, only the lower one was mined. At the Cave-in-Rock, at 18 feet depth, they have gone across the lower bed for 240 feet, at which distance it was cut off by a fault; some work was also

done on the upper one. The same methods pursued in re-locating faulted coal beds, will be of service where these beds are cut off.

An overthrust fault, pitching 35 degrees, having from 3 to 8 feet fluorspar, galena and quartzite, was stoped, and further efforts to intersect the master fault, at the Mary Mine. At the Rose, green fluorspar was mined, machinery installed, and a shaft sunk 115 feet, encountering quartzite and fluorspar. The Pell was re-opened, but not worked to any extent. A power plant was installed at the Hamp Fluorspar mine, and here, as at the Mt. Carmel Lead mine, development work was in progress. At the Hubbard mine, a broken-down bedded vein of crystallized fluorspar, covering a large tract at grass roots, was operated. The Empire vein, with gravel fluorspar and limestone, and zinc carbonate with a small per cent. of fluorspar, in rather distinct bands, was mined in a pit 50 feet in diameter, and 45 feet in depth. The main Empire shaft is reported to have four feet of solid white, highest grade fluorspar, with limestone walls.

Milling in Illinois.—Four new mills, the Evansville, Mary, Robinson, and Pierce, were put in operation; all for the separation of fluorspar and galena from gangue, except the last, which will grind in a Williams pulverizer dry crystallized fluorspar cleaned of red silicious clay by jigging. At the Mary mill, fluorspar and galena have been successfully and profitably separated for the first time from quartzite, in a mill somewhat of the Joplin type, using a Wilfley table for fines. The Robinson and Cave-in-Rock mills have complete sizing systems, and these with the Evansville, which is small, are equipped with New Century jigs, etc., and Ford tables, and are making marketable products.

The Fairview mill has been materially improved by the rearrangement of the picking belt, so that four now do the work that required twelve or more previously. The cylindrical washer has been cut out, and the shaking washing screen is now used alone.

At the Rosiclare an addition is being built to house Overstrom tables and a Hancock jig, the first of its type to be used in the district. The Hancock jig is to replace Harz jigs, in order that the daily capacity may be largely increased. The

Pell mill was in-operative. The Empire plant, which is equipped for washing and crushing fluorspar, and cleaning zinc carbonate, was in operation most of the year. Girls are employed for culling, and show great efficiency.

Central Kentucky District.—The Monitor Mineral Company was able to do but little at their fluorspar properties, the Twin Chimneys and the Fantail mines, owing to excessive water and lack of competent labor. These difficulties are to be overcome, and work resumed. The Twin Chimneys has reached a depth of 117 feet below the tunnel. At the Million calc mine, a tunnel is now being driven, and at 80 feet shows 5 feet of calcpar.

Colorado Districts.—No shipments were reported for 1906 from the Boulder district; one of the operators declared his deposit, from which shipments were made in 1905, was exhausted.

One hundred and twenty-five miles to the southward in Custer county, likewise in a region of Algonkian rocks and recent igneous intrusives, fluorite occurs locally in quantity in veins of the composite fault-fissure-breccia-replacement type; occurring in other parts, or in other veins, of the region more rarely and associated with gold tellurides. Near Silver Cliff, a fissure showing an average of 4 feet of solid fluorspar is being developed by R. W. Blackett, by means of a tunnel. Vein continuity has been proven for 500 feet, and some shipments were made in 1906.

Central Tennessee District.—The Rome Incline at 120 feet presents beautiful white crystallized fluorspar. At the Alcorn open-cut, on line of Southern Railway, the fluorspar increases in quantity amongst the limestone crevices, and shaft sinking is contemplated.* Here, amber-colored crystallized fluorspar is gotten. No lead or zinc secured at either property.

A 2½ foot vein of zinc and barite is being prospected in Smith county, by W. E. Minner. At the National Cemetery, near Nashville, Mr. J. E. Wright reports he opened a 1 to 2½-foot vein of fluorspar and barite.

*Private communication, D. C. Roberts.

SPECIAL SEPARATION PROCESSES.

As stated on a preceding page, successful separation of Western Kentucky fluorspar and zinc sulphides has been accomplished both by a non-acid flotation process and by electrical machines.

The Sanders Flotation Process.—Flotation processes for the concentration of sulphide ores depend in general on the floating of the pulverized particles by means of gases in a solution. The Australian processes all make use of acid solutions. Satisfactory results are reported from their application to Broken Hill, New South Wales, ores which contain more or less fluorspar. In the United States, Mr. W. Murray Sanders has recently patented a non-acid flotation process, which is now owned by the Sanders Ore Separating Company. This process is capable of effecting separations not attainable by any of the acid solution processes, as for example the separation of resin blende, and of solving also the more difficult problem of separating fluorspar from zinc sulphide. The great difference between this and other flotation processes lies in the basicity of solution and its selective power for zinc sulphide.

In this process, neutral or somewhat basic solutions of the earth metals as aluminum sulphate, etc., may be employed. By treating low grade bauxite with sulphuric acid, a solution consisting of aluminum and ferric sulphates is obtained. The solution should preferably be heated and have a specific gravity of 1.15 to 1.25. Sulphide ores treated in such a solution generate hydrogen sulphide, which serves to sustain and transport the particles of ore. Some of the advantages claimed for the process in the patent specifications (U. S. Patent No. 805,382) are: (1) The liquid remains remarkably clear and by virtue of the viscosity of the solution and its high surface tension, the particles are sustained for a very considerable period, and (2) non-corrosive character of liquid; both of these features admitting of considerable latitude in the choice of materials for, and construction of, separators. (3) Permits of fine pulverization of zinc sulphide (very necessary in Kentucky-Illinois zinc-fluorspar

ores) without serious losses in roasting, the decomposition of the earth metal oxide acting as a binder for the fine ores, reducing dust losses to a minimum. (4) Non-corrosive action of such binder toward zinc retorts being often beneficial, as opposed to the corrosive action of products of some of the acid solution processes.

The following description of the Sanders mill operated by the owners of the process, together with further details of the process itself, is based upon data kindly supplied by Mr. W. Murray Sanders.

The mill is located about three-eighths mile south of the depot at Marion, Ky., just east of the Illinois Central railroad. It is capable of handling problems involving the separation of lead, zinc and fluorspar.

The ore is received from the railroad switch and dumped upon an elevated platform from whence it is fed to the mill. It is passed through crusher, rolls and screens. All passing 20 mesh is fed to three Theurer tables, tables somewhat of the Wilfley type. These tables make three products, (1) galena, (2) zinc middlings, and (3) low grade fluorspar. (1) goes to lead concentrate bins, (2) is fed to Sanders flotation separator and (3) is sent to waste dump.

The Sanders separator consists of a lead lined wooden tank, 5 feet in diameter and 20 inches deep. Its capacity varies, with different ores, from 15 to 20 tons per day (single 10-hour shift). The flotation solution is prepared in a lead lined wooden tank, also. Low grade bauxite may be used, though the grade is immaterial. Sufficient sulphuric acid is added to obtain a solution of aluminum and ferric sulphates, having a specific gravity, according to the needs of the ore, varying from 1.15 to 1.25, the solution being heated 85 to 90 degrees Centigrade. Zinc sulphide treated in such a solution generates hydrogen sulphide gas, which serves to sustain and transport the particles of ore; neither the solution nor liberated gas appears to affect chemically the sulphides treated; that is, they show no apparent alteration. The lead particles, such as remain in the middlings from the tables, if any, are not floated by the solution, the zinc sulphide particles alone being floated. Such zinc particles flow off out of the solution and are allowed to settle in another tank, from which they are drawn off and sent to the concentrate bins.

The fluorspar separated usually contains too much silica to be valuable.

The percentage of recovery of total zinc sulphide in an ore depends upon the degree of dissemination and the consequent table recovery. The flotation recovery will run, according to Mr. Sanders, 80 to 95 per cent. The process has not been tried on middlings crushed finer than 60 mesh. The most suitable sized particles for treatment are said to be from 20 to 40 mesh.

The capacity of the plant is reported at 15 tons per day, (single shift). Eight men are employed and power is supplied by a 50-horse power common slide-valve engine and a boiler of like size. Water is secured from an artificial pond at the mill.

The cost of milling is said to vary with the character of ore treated; a 50-ton plant should operate at not over 75 cents per ton, total cost. For ore from the Nine Acres mine it is figured at 74 cents, 40 cents of which is allotted for preliminary concentration and 34 cents for subjecting to flotation process.

With the present table equipment Mr. Sanders reports about 60 per cent. of the original zinc contents as minimum recovery on the most difficult ores, and the probable average recovery for all ores he places at from 75 to 80 per cent.

In the prospectus of the Nine Acres Mining Co., the following results are reported on a test run of residue ore from the Nine Acres mine after the choice ore had been picked out and shipped. This is a typical mixed ore consisting of limestone, silica in form of jasperoid, fluorspar, galena and zinc blende, perhaps also some calcite:

Test run on Nine Acres ore, November 24, 1906:

Amount charged, 20,000 lbs. Assay: Zinc 14.9 per cent., lead 3.3 per cent.

Recovery from tables 5,450 lbs., containing zinc 44.4 per cent.

Final recovery, zinc concentrates, 2,900 lbs., containing zinc 58.4 per cent.

Lead concentrates, 690 lbs.

Repairing solution for flotation 65 lbs. acid.

The addition of a slime plant would materially increase the returns recorded above, as owing to the nature of the ore, a portion of it is unavoidably reduced to a condition of slime, which shows upon assay a similar composition to the original ore.

Signed: Sanders Ore Separating Co.

Examining critically the figures reported, we find the tables recovered $83\frac{1}{2}$ per cent. of the lead contents of the original charge. They show, also, a recovery of 81 per cent. of the zinc contents of the original charge; from the middlings subjected to flotation 70 per cent. was recovered, representing a total recovery of 57 per cent. of the zinc in the original ore. The percentages of loss in tailings and from sliming were not separately determined. The concentrates run 58.4 per cent. zinc and, according to Mr. Sanders, contained less than 1 per cent. of fluorspar.

The percentage of recovery from the tables while very good, might be increased, and this together with savings from slimed material should assist to materially increase the percentage of recovery. The character of the concentrates, if as reported, is satisfactory. The figures, to say the least, are highly encouraging and speak well for a probability of accomplishing the results hoped for by Mr. Sanders, that is, an average recovery of 75 to 80 per cent. for all ores, if proper care be taken in treatment. Especially are they favorable when it is considered they result from a double process, the treatment by tables and the re-treatment by flotation. Even if the recovery should not prove better than in the case of the Nine Acres ore, it would still be good enough to encourage Western Kentucky operators to exploit thoroughly their fluorspar-zinc ores, where the percentages are sufficiently high for zinc and lead alone; elsewhere in connection with the purer fluorspar veins, the zinc recovered would add nicely to the profits.

It is proposed to install a 50-ton plant as a result of the test of the Nine Acres ore, at the Nine Acres mine, which mine is to be re-opened by the Nine Acres Mining Co., as soon as arrangements can be completed.

Another difference is to be noted between the acid and basic flotation processes. In the former, the product is subjected to flotation first and to mechanical separation later, while in the basic process the treatment is in reverse order. According to figures submitted by Queneau to the Zinc Corporation* upon Australian ores, which differ most from the

*Engineering and Mining Journal, Vol. LXXXII, 1906, page 826.

Kentucky ores in having iron sulphide in the zinc blende, the percentage of zinc recovery, assaying 44 per cent., was 81 per cent. from the Potter flotation bath while that from the Sanders tables it may be seen ran practically the same. After treating by mechanical separation, the Australian flotation product yielded 71 per cent. of the zinc in the original product treated, these final concentrates assaying 50 per cent. zinc. The basic process makes a much higher grade concentrate (58 per cent.), though the recovery is somewhat less as would be expected; this compares favorably with the acid process, and gives promise of excelling it.

The electrical machines for which successful treatment of the zinc-fluorspar ores is claimed are the Sutton, Steele & Steele Dielectric Separator and the Blake-Morscher Electrostatic Separator.

The Sutton, Steele & Steele Dielectric Separator.—Messrs. Sutton, Steele & Steele have kindly supplied the following description, with accompanying diagrammatic sketch, of their apparatus, and of its method of separating pyrite, resin blende and fluorspar:

“The Sutton, Steele & Steele Dielectric Separator depends for its operation upon the difference in the dielectric capacity, or, in other words, the specific induction capacity of the particles under treatment, and not upon the difference in the conductivity of same.

“The principle can be readily understood if it will be borne in mind that dielectrics differ greatly in their ability to transmit electro-static lines of force, or, in other words, to allow induction to take place through their mass. In the present commercial application of static electricity to ore dressing other manufacturers separate the different particles of an ore pulp by the difference in their conductivity; the pulverulent mass being usually fed to a metal plate or cylinder which is charged with static electricity, the material of good conducting particles of the same being repelled *further than* the non-conductors.

“In the Sutton, Steele & Steele separator *none* of the particles are repelled. One class of particles adhere tightly to the cylinder or electrode, while the others drop *inertly* from it, while a rotating brush removes the adhering particles.

“In operation the material is fed to a rotating cylinder electrode which is connected to the earth and to which there is delivered from an adjacent electrode a convective or silent discharge through which the particles to be separated are carried while resting on the grounded electrode. The resulting conditions are such that the dielectrics are polarized, some more strongly than others. The electrical condition of these particles are in the same state as the glass dielectric separating the two metal coatings of a Leyden jar, which after discharge still shows a residual charge. The particles while resting on the grounded electrode receive a discharge of static electricity from the adjacent electrode and they thus have their opposite faces exposed to opposite electrical influences, and consequently each particle is divided in its charge having both + and — polarity. This is maintained and is the cause of their adhering to the electrode in a similar manner as iron filings do to the magnet.

“It has been discovered, however, that there is a difference in the time that dielectrics can be polarized, and in order to make separations between different dielectric particles it has been found expedient to deliver to the charging electrode a series of electrical impulses predetermined as to duration and time. The effect of this can be understood if we will take, for example, two dielectric substances such as zinc blende of the resin variety and fluorspar. Fluorspar polarizes more readily than zinc-blende, therefore if the electrical discharges are regulated as to the duration of time, the fluorspar can be polarized without affecting the zinc-blende and one can thus be separated from the other. It must not be inferred, however, that the Sutton, Steele & Steele separator does not separate conductors from non-conductors. It does so by polarizing the dielectrics while the conducting particles remain inert, being neither repelled nor attracted, and fall off the electrode unaffected by the current.

“The difference in the separation of the zinc-blende from mundic iron and zinc-blende from fluorspar is as follows: In the case of zinc and iron a continuous convective discharge is

maintained passing through the ore pulp and delivered to the cylindrical electrode. The effect is to polarize the zinc while the iron is not affected and drops inertly into a suitable receptacle. The zinc adheres to the cylindrical electrode (which is rotated during operation) and is brushed off into a separate receptacle.

"In the case of fluorspar and zinc it has been observed that the former will commence to adhere to the electrode sooner than the blende, and it therefore follows that if the electro-static charges are delivered in impulses, the duration or time of each impulse being of just sufficient length to affect the fluorspar without affecting the zinc, one can readily be separated from the other.

"For a scientific explanation of the phenomena we refer to our process patent No. 813,063."

Since electrical separators of other kinds have the particles under influence only a fraction of a second, and the time interval does not enter into the Sutton-Steele separator, the particles remaining until brushed off, it should make the best separation.

Sutton, Steele & Steele have given the Survey the following additional data concerning their machine: It operates on raw material without roasting, has a capacity of ten tons per day and requires only three-horse-power for separator and generator. When operating on the zinc-iron concentrates, or middlings, it will make a zinc concentrate carrying less than one per cent. iron and an iron product carrying from one to two per cent. zinc. They report that they have never tried the separation of barite and zinc or barite and fluorite with this machine.

Blake-Morscher Electrostatic Separator.—The Blake-Morscher separator operates on the principle of the relative electrical conductivity of minerals, some having a higher and others a lower conductivity. In this separator a metal cylinder is charged with electricity. The current of the cylinder affects sized ore particles, repelling those of like conductivity so that they are thrown over a divider or separating shutter, permitting the unlike conductive minerals to fall vertically. Minerals such as fluorspar and resin blende which are non-conductors may also be separated owing to their sus-

ceptibility to different degrees of conductivity. The Blake Mining & Milling Co., kindly furnished the Survey with samples of concentrates recently made with their separator. They were unable to divulge at present the locality from which the ore was received. From the samples it is apparent that the ore was a quartzite carrying red blende and fluorspar not unlike some of the ore of the Columbia lode. An assay of the concentrates of which those received were a sample is said to have shown them to carry 55 per cent. of zinc, while the tailings carry 3 per cent. zinc. The concentrates carry small percentages of fluorspar and quartzite, more of the latter than of the former, while the tailings consisted largely of quartzite with less fluorspar and little zinc. The particles are all under 1-20 inch. They report they have also done some remarkably good work in separating barite and zinc.

Considering the cost of mining, milling and incidental expenses at \$3.75 per ton, on a basis of 50-ton operation, and adding 20 per cent. per ton for profit, each ton of ore handled should have a gross value of \$4.50 per ton to make the extraction of zinc alone or zinc and lead profitable. The following table shows what percentage of zinc would be required in an original ore to yield a gross value of \$4.50 per ton, were the percentage of zinc recovery either 60, 70, 75 or 80 per cent. of that in the original ore, if the ore contained zinc only, or if it contained 1.25, 2.50, 3.75 or 8.25 per cent. of lead also, counting the lead yield upon concentrating at 80 per cent. or 1, 2, 3 or 5 per cent. respectively and the average value of lead at \$60 per ton, were the zinc to bring \$30, \$35, \$40, \$45, \$50, \$55 or \$60 per ton. Since the average value of zinc ore in 1905 was \$44.88 and in 1906 \$43.24 per ton, the percentages for these years lay between those for \$40. and \$45, and from this it may be judged about what is to be expected in 1907. Since the value of lead ore in the same years averaged \$62.12 and \$77.40, the average value of \$60 used for lead is believed conservative. Any value derived from associated fluorspar may simply be added to the profits; or it might be made to take the place of a part of the zinc and thus reduce the amount of zinc required.

TABLE VIII.

REQUIRED ZINC CONTENT IN ORE WITH A KNOWN PERCENT-
AGE OF RECOVERY FOR ORE TO BE VALUABLE.

Value of Zinc Ore								
f. o. b. cars		\$30.00	\$35.00	\$40.00	\$45.00	\$50.00	\$55.00	\$60.00
Per cent. of								
Recovery.	Percentage of zinc required in ore containing zinc only.							
60.00	25.00	21.43	18.75	16.66	15.00	13.60	12.50	
70.00	21.43	18.37	16.07	14.28	12.86	11.68	10.72	
75.00	20.00	17.15	15.00	13.33	12.00	10.91	10.00	
80.00	18.75	16.07	14.06	12.50	11.24	10.23	9.38	
Recovery.	Percentage of zinc required in ore from which 1 per cent. lead is recovered.							
60.00	23.66	18.56	16.25	14.43	13.00	11.80	10.83	
70.00	18.55	15.91	13.92	12.37	11.14	10.11	9.28	
75.00	17.33	14.85	13.00	11.54	10.40	9.44	8.66	
80.00	16.25	13.92	12.18	10.82	9.75	8.85	8.12	
Recovery.	Percentage of zinc required in ore from which 2 per cent. lead is recovered.							
60.00	18.33	15.71	13.75	12.21	11.00	10.00	9.17	
70.00	15.55	13.47	11.78	10.47	9.43	8.57	7.86	
75.00	14.66	12.57	11.00	9.77	8.80	8.00	7.33	
80.00	13.75	11.78	10.31	9.16	8.25	7.50	6.88	
Recovery.	Percentage of zinc required in ore from which 3 per cent. lead is recovered.							
60.00	15.00	12.85	11.25	10.00	9.00	8.31	7.50	
70.00	12.85	11.01	9.64	8.57	7.71	7.12	6.42	
75.00	12.00	10.23	9.00	8.00	7.20	6.65	6.00	
80.00	11.25	9.63	8.43	7.50	6.75	6.23	5.62	
Recovery.	Percentage of zinc required in ore from which 5 per cent. lead is recovered.							
60.00	8.33	7.13	6.25	5.55	5.00	4.53	4.16	
70.00	7.14	6.12	5.35	4.75	4.28	3.88	3.57	
75.00	6.66	5.67	5.00	4.44	4.00	3.62	3.33	
80.00	6.25	5.35	4.68	4.16	3.75	3.40	3.12	

CHAPTER III.

FLUORSPAR AND ITS OCCURRENCE.

Nomenclature.—Fluorite, fluorspar or calcium fluoride (CaF_2). Locally, it is often spoken of simply as “spar,” but as this term is also applied to barite, calcite, dolomite, siderite, quartz, etc., the usage should be discontinued. The writer uses the term “spar” in speaking of two or more of the minerals, fluorite, barite, or calcite.

Fluorite was written of by Agricola in 1529 as “fluores lapides,” meaning literally “flux stone;” hence, the name. It was called “fluss spat,” the German for fluorspar, by Cronstadt in 1758, while Napione called it fluorite in 1797. Locally, in England it has been called Derbyshire Spar and Blue-john. For further notes on nomenclature, see Dana’s System of Mineralogy.

Crystallography.—Fluorspar occurs crystallized in cubical clusters found lining vugs, seams, in breccia, and in red clay. Crystals up to ten inches across have been found, commonly as penetration twins. Single perfect cubes are exceedingly rare, and quite small. Only one natural octahedron has been seen by the writer. Fluorite clusters are comparatively rare, and perfect ones extremely so. Crystal varieties are locally known as crystal or glass spar. Plane-faced cubes are exceptional, the faces consisting usually of small cubes arranged in parallel position, rather in step fashion. Crystals showing flaws exhibit a play of colors along the plane of fracture. Crystal faces show etching at times. Crystals showing two periods of decomposition have been found; for example, yellow fluorite, considerably etched, forms the basal crystal, then a purple layer above, and between the two minute pyritehedrons are found. This probably represented a redeposition of the fluorite that has been corroded, practically in its original place.

The largest number of crystal groups, as well as the largest groups in size, are obtainable from the bedded veins, such as on Lead Hill, where they have been formed between the lamination and bedding planes of the limestone, the crystals often making room for themselves. They occur in these instances interlacing each other comb fashion. Also groups, originating in this manner, may be double, the crystals having formed on one side of the original layer of limestone, the upper side, for example, forming a group of small sized crystals, while the group on the under side consists of large crystals, and vice versa.

Casts of fluorite crystals and occasionally fluorite, are to be found in smithsonite. It is a question whether such crystals are secondary or are residual of the original vein, the smithsonite having formed about them.

Besides the characteristics pointed out for crystals of fluorite of the Kentucky-Illinois district, elsewhere fluorspar occurs also occasionally, according to Dana, in octahedrons or dodecahedral forms, while fluoroids and hexoctahedrons are common. Cubic crystals occur sometimes grouped in parallel position, thus forming a pseudo-octahedron. For a list of observed forms of fluorite crystals, reference is made to Dana's work.

Structure.—For the most part fluorspar is granular massive. As originally formed in fissures, the fluorite was coarsely crystallized. The granular condition was induced secondarily by crushing, due to pressure of the hanging wall and the superincumbent fluorite mass. Lateral and vertical pressure also results, jointing the fluorite into blocks. As fluorite has only a hardness of 4, and is brittle, the granular condition was readily brought about. The grains are from fine to coarse. Further pressure, usually later, results in sheeting, and, hence, ribbon structure. See following plate. Sometimes such sheeting planes are slickensided and grooved, as at the Memphis incline. Where it is more pronounced, usually immediately against one of the walls, the fluorite at times assumes a lamellar-fibrous condition, seen in specimens from the Bill Terry mine. Still greater pressure results in white compact fluorite, while the extreme end product is white or slightly colored earthy

fluorspar powder, finer at times than the finest mesh ground of the mills, such as was secured at the Mary Belle mine in Crittenden county. Fluorspar also occurs in gravel form. No columnar fluorspar has been seen in the Kentucky-Illinois district, though it occurs elsewhere, as in Derbyshire, England.

Fracture, Hardness, Density, etc.—Fluorspar has a flat-conchoidal fracture; more rarely round conchoidal, as in amorphous cleavages (optical fluorite), and splintery in the compact kinds. It is brittle and has a hardness of 4.

The specific gravity of fluorspar varies from 3.01 to 3.25, an average of 3.13.

Luster, Streak.—Its luster is vitreous, usually glimmering in massive varieties; sometimes splendid. Compact or powdery earthy varieties are dull. When deep purple-black in color and opaque, it shows a sub-metallic luster.

Fluorspar upon powdering becomes white, that is, it presents a white streak; the deep purple-black variety shows a heliotrope streak.

Color.—It occurs in nature in all colors, but in Western Kentucky it has been found white, purple, amethystine, reddish, gray, brown, amber-yellow, purple-black, and rarely pellucid. In Southern Illinois it occurs also blue and green. Nearly all the fluorite when freshly broken, yields the odor of hydrocarbons. Wyrouboff and Von La Saulx attribute the color assumed by fluorspar to them, rather than to metallic oxides, and tests made by the writer tend to confirm this view. Smith* suggests that the color may be due to oxidation of the hydrocarbons, since they are found in colorless fluorite, as well as in the colored. Field observations and specimens collected by the writer agree with this. In the writer's opinion the fluorite occurred originally either colorless or brown, according to the amount and density of the contained hydrocarbons; that containing light hydrocarbons is white or colorless, and that containing heavy ones is brown. The fluorite encased in unweathered barite is always colorless; that in softened barite, and where calcite had been

* W. S. Tangier Smith, U. S. Geological Survey, P. P. 86, 1905, p. 125.

present and has leached, is often purple. This is, in a manner, proof of the oxidation theory. Fluorite associated with carbonaceous shale walls, as at the Lucile mine, is brown, sometimes altering to purple. Brown fluorite will also occur more largely in replacement deposits than white. The only yellow that has been noted occurs in the zone of oxidation. The purple seems to represent a higher state of oxidation than the yellow, for crystals are found in which the color changes from purple to yellow as distance from the crystal face is reached. The green crystals of fluorspar found in Southern Illinois occur in surface clays, except in one instance the writer secured a piece of light green from the 300-foot level of the Rosiclaire, though it is possible that it was oxidized in a vug. The fluorite secured in depth is invariably gray to white, except where the walls have contained heavy hydrocarbons. A large part of the hydrocarbons, as has already been pointed out by Smith, occurs between grains, and represents later depositions than the mineral itself. This is true most largely for the brown fluorite, which also shows hydrocarbon inclusions. Such are necessarily primary. Smith thinks decrepitation of the fluorspar upon heating, depends largely on the extent of hydrocarbons present.

White crystals from Bonanza, and amber-colored ones from Tabor, both show purple coatings on the edges. Such coatings are noted to some extent on corroded fluorite. In one instance fine granular was especially heavy charged with hydrocarbons, and was of a dark brown color, and of dull earthy luster. Fluorite, where containing galena, is often stained green by minute fibers of pyromorphite. The reason why the fluorite should become colored and the calcite remain white, is difficult to comprehend. Hydrocarbons occur in some of the calcite, and some of it becomes slightly brown from them, but no other color is apparent. This may depend on the difference in molecular state of fluorite and calcite, or, again, it might be that some interaction between oxidizing agents may take place in the presence of fluorite that can not in the presence of calcite. Where manganese oxides color minerals, calcite, when present, is colored pink, so that this presents an argument in itself against the coloring of the fluorspar by manganese.

Colored crystallized fluorspar shows dichroism, to some extent,—that is to say, it exhibits different shades of color as the crystals are turned, the color arranging itself in intense lines parallel to the face of the cube. This is most commonly exhibited in crystals of purple shades. Colors are more intense in thick cleavages than in thin.

Single crystals have been found exhibiting three different colors, one faintly blending into the other, as red, white and blue. The crystal surfaces are usually dull. The color is always more pronounced by transmitted than by reflected light.

No. 1. fluorspar, white, occurs usually in open fissures, having Ste. Genevieve or Tribune as one or both walls; less often St. Louis forms one or both walls. Brown or dark colored fluorspar, coarse crystalline, is found, in a large measure, associated with bituminous shale walls. In some instances, notably in Caldwell county at the Senator and Marble mines, it occurs of similar color in Ste. Genevieve limestones. Finer grained dark fluorspar occurs replacing limestone, either of Princeton or St. Louis, and is associated with jasperoid, hence, silicious. Such fluorspar frequently has fine grained zinc and small cubical or granular galena. The frequent association of purple fluorspar with St. Louis is not surprising, considering the ready access that oxidizing agencies have for it. Whenever a sufficient depth below such agencies is gained, the fluorite with St. Louis walls will also be white.

Phosphorescence, Fluorescence, Electrical Properties.—Neither phosphorescence under ordinary conditions, nor fluorescence, were discernible in Kentucky or Illinois fluorite in tests made both by the writer and Dr. W. S. Tangier Smith. Upon sufficient heating, it becomes phosphorescent.

Fluorspar from some localities elsewhere exhibits both white and green (latter in chlorophane) phosphorescence and a bluish fluorescence. The chlorophane variety is sometimes both thermoluminescent and triboluminescent, (as that from Amelia Court House, Va., which contains considerable yttrium and ytterbium), these conditions being, according to Kunz, due to molecular instability. Fluorspar exhibits, according to Dana, difference of electrical potential between

the faces and angles of a cube, both under the action of heat and of light.

Refraction.—Refractive index for Na $N_y=1.4339$, Sarasin; $N_y=1.4324$ (gray) 1.4342 (black), Kolrausch. The index diminishes slightly with an increase of the temperature. (Dana).

Sometimes it exhibits anomalous double refraction. The writer has been unable to find this feature in any of the Kentucky or Illinois fluorspar.

Composition.—Fluorite consists of 48.7 per cent. fluorine and 51.3 per cent. calcium, when pure. Clean natural fluorine seldom falls below 9 per cent. calcium fluoride, while some of the No. 1 runs over 99 per cent. Perhaps not one-eighth of American fluorspar marketed will run less than 80 per cent. The lower percentages are due to its being associated with such minerals and rocks as calcite, barite, limestone, quartzite, etc.

The following typical analysis of commercial fluorspar kindly supplied by shipping companies are of interest:

Description of samples.	Calcium fluoride.	Silica.	Calcium and Magnesium carbonates.	Iron oxides.
Ground Fluorspar: Memphis Mines, Kentucky Fluorspar Co.	99.95	Trace	Trace	
Ground Fluorspar: Hodge Mines, Kentucky Fluorspar Co.	98.80	.21	.98	
No. 2. Ground: Nancy Hanks Mines, Albany Mining & Investment Co.	96.00	.71	3.29	Trace
Typical Fluxing: Gravel Fluorspar, Kentucky Fluorspar Co.	95.08	1.90		
Typical Fluxing: Gravel Fluorspar, Kentucky Fluorspar Co.	95.47	1.52		
Fluxing Gravel Fluorspar average of three cars: Pogue Mine, Marion Mineral Co.	96.83			

See page — for an analysis of common English fluorspar.

Varieties.—Besides ordinary fluorspar two varieties may be distinguished, that exhibiting green phosphorescence called *chlorophane*, and that containing free fluorine, which Schoenbein has named *antozonite*.

Physical Determination.—Fluorite may be readily distinguished from most of the minerals of the Kentucky-Illinois district. It will scratch calcite, but not glass, as does quartz. It does not possess the milky white color that calcite most frequently shows. It breaks into tetrahedral plates and octahedral cleavages, while calcite always shows rhombohedral cleavage. Fluorspar does not effervesce with acids as do calcite and smithsonite. None of the other minerals are affected by the glass etching test given below. It can not be confounded with galena, as the latter has always a lead gray color, on fresh surface, shows a metallic luster and is twice as heavy. Sphalerite often has a resinous luster, where fluorite has a vitreous to splendent one. Barite is heavier and has a fibrous structure usually, which fluorite does not show. Barite, fluorite, galena, calcite and sphalerite, all decrepitate on heating; hence this property is of no value in distinguishing them.

Fluorspar, when heated in a closed glass tube, decrepitates and phosphoresces. Before the blowpipe, in the forceps and on charcoal it fuses, coloring the flame red, to an enamel which reacts alkaline on test paper. With soda on platinum foil or charcoal, it yields a residue of a difficultly fusible enamel, while most of the soda sinks into the coal; with gypsum it fuses to an opaque bead, becoming transparent on cooling.*

According to Brush-Penfield, its fusibility is 3 of the usual scale; a fragment of 1.5 mm. in diameter fuses readily to a globule before the blowpipe; in a luminous lamp or gas flame only the very finest splinters or thinnest edges are rounded.

For chemical tests both, qualitative and quantitative, refer to the chapter on Methods of Analysis.

RARE ELEMENTS IN FLUORSPAR.

This subject has been rather fully investigated by Prof. W. J. Humphreys, who examined specimens of fluorite from all parts of the world, especially for yttrium and yttrium, and the results of whose investiga-

* Dana's System of Mineralogy, 6th Ed. 1901, p. 163.

tions have been published.* Upon these, together with data kindly given the writer of his as yet unpublished results, the statement here presented has been based. Yttrium and, probably, to a less extent as a rule, ytterbium as well, occurs in practically all fluorspars; and, since fluorspar alone of the minerals in which they are found, occurs to any appreciable extent, it is the most available source of these elements. None of the other rare elements, such as cerium, thorium, lanthanum, the didymiums, samarium, tungsten, uranium, etc., nor cobalt was detected in even those fluorspars from the regions of these elements, and rich in yttrium and ytterbium. No sort of connection between the amounts of yttrium and ytterbium could be traced to the color of the fluorspar. It was not possible to determine whether or not manganese was present, since it was always present in the light carbons used.

In regard to the presence of these elements in fluorspar of the Kentucky-Illinois district, Prof. Humphreys found a trace in the specimen from the Asbridge mine, and a small amount in that from the Columbia, while in that from several of the large Crittenden county fluorspar mines, (Memphis, Klondike, Hodge, Tabb, Edwards, and Givens mines) none was detected. He thinks that it is probably concentrated where little fluorspar occurs, as in the Columbia mine, and also present, but in so diluted a state as not to be detected, where great masses of fluorspar occur. He found traces in the three specimens examined (one from Rosiclare) from Southern Illinois, and also a trace in fluorspar from the Twin Chimneys mine in Central Kentucky.

So far as the present writer is aware, neither yttrium or ytterbium is of practical value in the arts at present, owing to their rarity. Yttrium oxide was tentatively used by Welsbach in the early manufacture of the Welsbach mantles, but this practice has been discontinued, and only thorium and cerium are now employed.

Fluorine in a free state, according to Dana, occurs in dark violet-blue fluor (called antozonite by Schoenbein) of Wolsendorf, Bavaria, the strong odor of which is said to often produce headache and vomiting in the miners. In the Kentucky-

* *Astrophysical Journal*, Vol. XX, 1904, pp. 265, 273, and Vol. XXII, 1905, No. 2.

Illinois fluorspar hydrocarbons occur, which are discussed under "Color;" they also are productive of a strong odor, especially when the fluorspar is struck a blow; it may be that in some instances the odor is partly due to free fluorine. Chlorine is also present at times in minute quantities.

Encrustations and Inclusions.

Calcite, barite, quartz, and smithsonite in crystals or mammillary form, are commonly found encrusting fluorite crystals; more rarely pyromorphite, galena and sphalerite crystals also are seen in such position.

Inclusions of hydrocarbons and pyrite cubes and tetrahedrons are most common, while more rarely galena and sphalerite occur similarly. In Central Kentucky, inclusions of an undetermined mineral have been noted at the Twin Chimneys mine.

Artificial fluorspar: Made by Sheerer and Dreschel in crystallized forms. (Dana).

Genesis.

The writer has elsewhere discussed the genesis of fluorite in detail.*

The conclusions reached regarding the origin of Kentucky-Illinois fluorite are, briefly: Fluorspar consists of calcium and fluorine. The wall rocks form a ready source of calcium, but contained little or no fluorine. Igneous dikes of mica-peridotite, a dark green rock consisting of more than a dozen minerals, two of which, biotite and apatite, usually contain more or less fluorine, traverse the district. Upon analysis, this rock, none of which is very fresh, now shows very little fluorine content, yet it, together with the underlying mass from which it was given off, or the underlying mass alone, seems the most probable source of the fluorine. The compounds ultimately to form the deposits were transported by means of ascending thermal or heated solutions, coming as an aftermath of the eruption resulting in dikes. The fissures, faults, and dike contacts formed trunk channels along which

* Livingston County, Its Mineral Veins and Other Resources, Bull. 9, 1907, Kentucky Geological Survey.

the waters ascended, and to some extent the waters spread laterally from these into the adjacent rocks, metasomatic deposits resulting. The fluorine was probably brought up in the form of hydro-fluosilicates of lead, zinc, copper, calcium, barium, etc., as first suggested by Dr. Bain, and also found by the writer to nearest fulfill the conditions. The separate deposition of silica from fluorine is best explained by attraction due to mass action, silica being attracted to sandstone to form quartzite of it, the fluorine being left free to exercise its affinity for calcium in the solutions, or to replace limestone. In most instances of replacement, silica and fluorspar were deposited together, forming jasperoid-fluorite, as at the Evening Star mine. Perhaps such mutual deposition of silica and fluorspar depends upon some principle of replacement not now understood. A number of processes were involved in precipitating the deposits from the solutions, as decrease of heat and pressure, intermingling of solutions, etc., but the most important were the inter-reactions of calcium bicarbonate and hydrocarbons, with the fluorine content of the fluosilicates, which resulted in the formation of fluorspar, while hydrogen sulphide united with the metals and precipitated them as sulphides.

According to Mendeleef some hydrocarbon compounds result from the addition of a halogen acid to a carbonate of a metal. Thus the combination of calcium (CaCO_3) hydro-fluoric acid (2HF) results in the formation of fluorspar (CaF_2) and the hydrocarbon compounds CH_2O_3 . This explains a source of hydrocarbons in fluorspar in addition to those organic hydrocarbons, already in the limestone, to be dissolved or replaced previous to the deposition or formation of fluorite. The hydrocarbons so formed are probably in part the source of the coloring compounds in fluorite.

Nothing definite can be said as to the age of the deposits, but they were formed shortly after the intrusion resulting in the dikes, which was between post-Carboniferous and late Tertiary, probably in early Tertiary time.

The Central Kentucky and Central Tennessee deposits are somewhat similar, but differ in absence of extensive faulting and igneous dikes. Shaler has suggested the origin of the Central Kentucky fluorite to have been from the sedi-

mentary rocks, but sufficient data is not at hand to determine. The writer could find nothing in literature relative to the origin of the Castle Dome, Arizona, fluorite.

Ransome and Lindgren consider the fluorine of the fluorite of the Cripple Creek region to have been given off in volatile form from phonolite magmas on their consolidation at higher levels; also suggest a similar origin for that of the Black Hills, Judith Mountains, and Little Rock Mountains. That of the Telluride district originated, according to Purington, from the lower lying igneous rocks from which it was brought up by ascending solutions. The Albermarle county, Virginia, fluorite is associated with chlorite schist and quartz, and it had clearly an aqueo-igneous origin. That at the Einstein mine, in Missouri, also, according to Bain, was derived from igneous rocks. In Europe, Stelzner, Beck, Mueller and others attribute the origin of fluorite of the Freiberg and Saxony districts to thermal solutions, deriving their content from the igneous rocks. The English fluorspar deposits are generally conceded to have had the fluorine derived from nearby or associated igneous rocks.

For a classification of genetic types of deposits with which fluorspar is usually associated refer to page 73.

Fluoritization.—The formation of fluorite by means of metasomatism or replacement of another rock or mineral is termed fluoritization.

The replacement of the wall rocks by fluorite is not uncommon in the Kentucky-Illinois district. It occurs, replacing calcite and limestone abundantly; and quartzite and chert to a less extent, because of their less solubility. The replacement process was one involving a complete dissolution of the limestone and simultaneous deposition of the calcic fluoride formed, while in fissure filling the limestone was previously dissolved and the reaction and deposition were subsequent. The fluorite, where occurring as a replacement product, occurs largely in fine granular, partially developed crystals, and either brown or purple in color, depending on the state of hydrocarbons present. Fluorite has been found in a number of instances partially replacing silicified corals, such as *Lithostroton*, etc. Much of such fluorite occurs associated with

jasperoid, a rock consisting of minute quartz dihexahedrons resulting from the replacement of limestone by silica. Emons has suggested that, originally calcite may have filled most of the fissures and it was replaced by fluorite; but, as it appears difficult to explain an interchange of constituents, and complete re-dissolution would become necessary, the writer does not consider this probable.

Fluoritization is not uncommon elsewhere where fluorite occurs. Lindgren says fluorite may replace many other minerals. It has generally a purplish, unevenly distributed color, and shows under all circumstances a strong tendency to crystal-development. He described a specimen of limestone breccia from the Judith Mountains in Western Montana, showing replacement by a crystal of fluorite, the sharp angles of the cube projecting into the limestone, and explains this as a case of complete replacement. Fluorite, together with quartz and pyrite, is further formed, according to the same writer, as a replacement product of orthoclase in the Cripple Creek District, Colorado. Fluorspar occurs as one of the accessory minerals in "greisen," the alteration product which occurs in connection with tin deposits in granite rocks.* See page 75.

Alteration.—Fluorspar seldom occurs altered except in the belt of weathering.

Fluorspar is seldom leached out of ore. Cavities occurring in the ore are usually due to the leaching out of calcite, limestone, sphalerite or galena, and such leaching frequently results in honey-combed fluorite. More rarely fluorite shows cavities the result of etching either by alkaline carbonates or ammonium sulphate. Some of these are exceedingly minute, and give to it the appearance of a fine network of a bryozoa, such as fistulipori. Again, it is riddled by larger cavities, the size of a pea or slightly larger. Again, the effects of corrosion are simply to dull the crystal faces, or to give them a rough hackley appearance. Fluorspar showing the varied effects of corrosion may be seen at the Tyrie mine

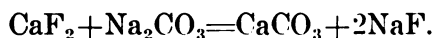
* "Greisen" is a German term and means cleave or split. It is the result of alteration of granite and is found in connection with certain copper and silver-lead veins, as well as adjacent to certain tin veins. It consists essentially of quartz and white mica, replacing feldspar, with some other minerals. Fluorspar is one of several minerals that characterize tin-bearing greisen.—C. J. N.

in Caldwell county. It appears more readily corroded paralleling the cleavage planes.

Gravel Fluorspar.—In the belt of weathering numerous deposits of gravel fluorspar occur. Such bodies vary from a few inches to thirty-six feet in width. The gravel occurs granular, from grains exceedingly minute to those that will pass an inch mesh screen, while lumps occur through it occasionally, some of considerable size. In rare instances the gravel deposits contain numerous fragments of fluorite crystals. It is possible that such are the result of concentrations in clay, but part at least may have occurred in the original deposits. Such spar is usually from a reddish earthy brown to purple in color, the red color being due to ferric oxide stains. Rarely gravel is white to purple, but such usually occurs only some distance below water level. Gravel fluorspar results from the disintegration of massive granular fluorite, sometimes of crystal fluorite. Fluorite is practically insoluble in surface waters, one part being soluble in twenty-six thousand; hence, while the limestone walls are being attacked by surface waters and disintegrated and dissolved, the fluorite resists their action. However, after the wall on either side begins to give way the residual products formed are taken up by the waters, and these permeate between the granules, along cleavage and sheeting planes of the fluorspar, depositing their quantities of silica and ferric oxides. When such crystallize between the grains they have the tendency to expand or enlarge, and, hence, to disrupt the mass. Where one or both of the walls consists of chert or quartzite these prevent disruption, since they are but little affected by weathering, as at the Tabor shaft where the walls were chert and quartzite. If one wall is of such material, the fluorspar near that side remains more or less intact. In some instances the fluorite resists the action of weathering for a considerable time, but after the walls are completely gone and the process of disruption has continued far enough, the fluorspar disintegrates and falls down. By such time the walls are usually dissolved down to water level and the spar may fall on either side of the less weathered fluorite below, which in them becomes further weathered till it disintegrates, and so till in

some cases as much as seventy feet below water level is changed to the gravel form. Because of the falling down on either side of the vein of the fluorspar that was above, the veins of gravel are wider, sometimes several times the width of the original vein. All of the deposits of gravel fluorspar that have yet been exploited have shown the original vein in depth, indicating that little, if any, of the fluorspar has been carried any distance, that is, no placer deposits have been found. Ribbon structure in lump fluorspar may present white and purple or white and brown colors in alternate bands, depending on access of oxidizing solutions to the various narrow sheets, the more open ones being of darker color.

Fluorspar alters to calcite according to Van Hise,* by alkaline carbonates according to the equation:



No such occurrence has been noted by the writer.

A subsequent alteration of the calcite results in a number of minerals forming pseudomorphs (appearing in a crystal form of another mineral) of fluorite. Fluorspar occurs changed to quartz by substitution, also to limonite, hematite, lithomarge, psilomelane, calamine, smithsonite, cerussite, kaolinite.†

Occurrences of Fluorspar.

Western Kentucky District.—The rocks of the district consists largely of limestone, sandstones and shales of Carboniferous age. Rocks of Quaternary age also occur in the western part of the district, and, where occurring, hide all trace of the ore deposits, since such rocks were deposited at a later date than the deposition of the ores. The following table gives the formations occurring in the district:

* A Treatise on Metamorphism, Monograph XLVII, U. S. Geological Survey, 1906, p. 216.

† Dana, System of Mineralogy, 6th Ed. 1901, p. 163.

TABLE X.
GEOLOGICAL FORMATIONS.*

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Recent.	Alluvium, (recent).	Alluvium	Feet. 0-40
Quaternary. (Pleistocene.)	Columbia Formation.	Fulton Loam (Brown loam).	0-15
		Port Hudson clays.	0-10
	Lafayette Formation. (Stratified drift).	Paducah Formation { Brown gravels, finesand, sand- stone.	5-30
		Tennessee River Gravels { White Gra- vels, Clay.	20-110
		Allegheny Formation { Sandstones, Limestones, etc., workable Coal beds.	60-100
CARBONIFEROUS.	Pennsylvanian, (Coal Measures).	Pottsville Formation { Superior Sand- stone and con- glomerate, Inter-conglom- erate Coal and Shales, Inferior Sand- stone and Con- glomerate.	0-97 10-18 40-100
	Mississippian, (Subcarboniferous; Lower Carboniferous).	Lockhart Formation { Limestone Shales, some Sandstone.	100-175
		Birdsville Formation { Alternating Sandstones, Limestones and Shales.	315-630
		Tribune Limestone.	100-150
		Cypress Sandstone (Ferruginous sand- stone of Illinois and, in part, also of Missouri).	60-150
	Ste. Genevieve Limestone. (Princeton limestone).	Ohara Limestone.	31-121
		Rosiclare Sandstone.	1-25
		Fredonia Limestone.	115-150
	St. Louis Limestone.	St. Louis Limestone.	300-500
	Tullahoma Formation. (Lower Silicious; time equivalent of Keokuk- Waverly).	Tullahoma Formation.	200-225
Devonian.	Ohio Shale. (Black shale).	Ohio Shale (under cover).	45-100

* See writer's report on Livingston County, chapter II., for discussion of correlation and details of stratigraphy.

The district has undergone both regional and local disturbances with attendant fracturing and faulting, with subsequent intrusion of basic igneous rocks, (mica-peridotite (in Southern Illinois pyroxene-lamprophyre) dikes and sills), and, later, the deposition of minerals from ascending thermal solutions along the faults, fractures and contacts. The faults and fractures are arranged along such zones. Such zones are often several miles in length, while the individual faults and fractures are usually less than fifteen hundred feet in length. Cross faults occur at somewhat constant angles to those having the trend of the zone. The faults and fractures are often arranged *en echelon* (in step fashion) and often as approximate parallels. They strike both northeast and northwest, and all carry more or less mineral, although most of the mines operating are on the northeast strikes. The accompanying plates show a sketch map of the Memphis mine group, (which presents typical geological conditions), and a cross-section of the same.

Owing to faulting and subsequent erosion, anywhere from a few feet to more than fourteen hundred feet of the upper strata, are gone in various parts of the district, leaving a checkerwork of unlike contiguous strata blocks bounded by the fault zones to be seen on every hand. The character of the faults and fractures with methods of fault location, are discussed in Chapter IV.

The principal minerals occurring associated with fluor-spar in the Kentucky-Illinois district, are barite (barium sulphate), calcite (calcium carbonate, calcspar), galena (lead sulphide), smithsonite (zinc carbonate), and sphalerite (zinc blende, resin blende, jack, zinc sulphide). Less frequently ankerite, bitumens, calamine, cerussite, chalcopyrite, copper, greenockite, hydrozincite, laolinite, limonite, malachite, marcasite, pyrite, pyromorphite, quartz, sulphur, stibnite and wad. The minerals may occur in the veins intimately intergrown, in separate bands, or more rarely the vein may consist of but one mineral. The deposits occur filling open fissures, some as replacements of the wall rock adjacent to the veins, some cementing brecciated wall rock, while still others are a combination of fissure filling, replacement and breccia deposits.

The largest ore bodies are found in the locally more fractured parts of the district, and where the wall rocks are suitable to deposition. The minerals of the veins extend practically to the surface in all cases, there being a covering usually of less than fifteen, and, in extreme cases, up to forty feet of the surface debris. Difference in elevation only affects the ore bodies in that those above ground-water level may be somewhat altered by weathering. The ores will extend to a depth greater than it will be profitable, under the present conditions, to mine them, some of them perhaps to a depth of two thousand feet. The character of the mineral not only differs often in the cross and approximately parallel veins, but often in a short distance along a vein. The changes in depth depend largely upon changes of wall rock, as from quartzite, to limestone, etc. There is no evidence of decrease of fluorspar in depth. Some of the veins are barren. Along the veins pinches and swells occur, and the ore bodies sometimes reach a width of thirty feet or more, though the average vein is four feet or less. Excepting for alteration of the minerals due to surface waters, the same minerals that occur near the surface occur in depth. Zinc carbonate deposits occur in part as reconcentration of eroded veins, while the gravel fluorspar likewise results from broken down veins.

The probable extent of the fluorite deposits of Western Kentucky, even if considered very conservatively, is so enormous as to appear almost beyond reason. A careful calculation of the probable fluorspar content of a single county of the district, Livingston county for example, basing the calculation on its 162 miles of fault zones or major lodes, and allowing an average width of four feet of mineral to depth of 1,000 feet, assuming also only that one-fifth are filled, exceeds the enormous amount of 66,900,000 short tons. Crittenden county is capable of producing as great, perhaps a greater, amount, with Caldwell also able to yield an enormous tonnage, while the other three counties—Christian, Lyon and Trigg—may also yield a share, making the extraction for the district, to a depth of 1,000 feet, of close on to 200,000,000 tons a possibility. According to Dr. Kent's* figures, the production of pig iron for the first half of the Twentieth Century, would be 10,230,000,000 gross tons.

* *Manufacturers Record*, Vol. LI, p. 62, 1907.

If the amount of fluorspar used in iron and steel making remained the same as in 1905, i. e., about 0.28 per cent. of the flux used, 8,184,000 tons of fluorspar would be necessary in the consumption of the iron suggested by Dr. Kent. If the total American fluorspar consumption for the period named, were from the amount named to double it, Western Kentucky would still be able to supply any and all demands made upon it for from six to twelve centuries, by which time all available supplies of iron would also be consumed, should the production continue. In addition, it is capable of turning out no small tonnage of lead, zinc, barite and calcite.

There are about two hundred and twenty-three mines and prospects in the district. Of these more than seventy are or have been producing lead, zinc, fluorspar, calcite or barite singly or several of these minerals together, and of such mines the location may be learned from the sketch map of the district accompanying this report, which also shows the location of the principal prospects in those counties not having producing mines. Of mines and prospects at which some of the previously mentioned minerals have been found in Crittenden county, there are 127; Livingston county has 50 and Caldwell county 19. Of counties in which but little development work has been done, Christian county has 8 prospects, only one of which has as yet shown lead and fluorspar; Lyon county has 6 prospects, three of which show some lead, zinc and fluorspar; two have calcite and one manganese ore; Trigg county has 11 prospects all save three of which show fluorspar, etc. Union county, while not strictly a part of the district, has a large fault on or near the line of the Rough Creek anticline, with which is associated barite in sheeted quartzite that would bear investigation. Webster county shows some zinc blende in siderate concretions in the Coal Measures.* In Chapter VIII is given a rather complete list of the mines and prospects of the several counties, showing their location, ownership, when and by whom first prospected, when last operated, and synonymous names.

The Western Kentucky lead, zinc and spar district has iron ore of good quality in quantity within its borders, as

* A frequent occurrence in the clay iron stones of the Coal Measures in Kentucky as elsewhere.—C. J. N.

well as an abundance of high grade calcite and limestone flux, and coals of the Western Kentucky coal field within easy reach, so that with the fluorspar it has, it should with additional transportation facilities become at no very distant date a center of iron and steel manufacture.

Many of the important details and characteristics of the occurrence of fluorspar in Western Kentucky are considered first under each heading in this chapter, after which details of other districts are noted. Other details of the Western Kentucky district are to be found in the chapter on prospecting and mining methods, and in the chapter on milling methods, where details of ore structure and their economic phases are discussed.

Southern Illinois District.—The data given for the Western Kentucky District holds good also for Southern Illinois, since they form a part of the same stratigraphic, geotectonic, petrographic and metallographic province.

Central Kentucky District.—This district comprises Anderson, Bourbon, Boyle, Clark, Henry, Fayette, Franklin, Garrard, Jessamine, Mercer, Owen, Scott and Woodford counties.

The veins, which vary from a few inches to 7 feet or more in width, the usual width being from 1 to 3 feet, traverse Ordovician limestones from the basal member (Camp Nelson limestone) to the top of the Trenton, while the faults affect still higher members. The region has been affected by the Cincinnati geanticline, and has a number of faults, the largest and most continuous of which is the Kentucky River fault. The veins, so far as examined by the writer, show little or no faulting. The vein minerals are usually barite and fluorite, most of the veins showing a preponderance of barite, a few of fluorite. Associated with these minerals are greater or less amounts of lead and zinc sulphides, more rarely other minerals as celestite, smithsonite, etc. Nearly all the veins fill tension fissures, and trend nearly north and south. The veins are largely fissure fillings, and many of them show crustification, bands of fluorite, barite, and calcite, alternating, as at Twin Chimneys mine. The most notable fluorspar occurrences are those of the mine just mentioned, and

the Fantail mines, both in Mercer county. Again the minerals occur much intergrown as fluorspar, barite and galena, barite, galena, and sphalerite, etc. The fluorspar is white, and but little affected by weathering after a short distance from the surface is reached, and if separated from the barite, would be extra No. 1 in grade. Numerous white or nearly colorless crystal groups occur. Bulletin 2 of the Kentucky Geological Survey, by Prof. A. M. Miller, may be referred to for details of the geology and descriptions of some of the individual deposits.*

Central Tennessee District: This district is analogous to that just described in the type of deposits and age and character of rocks traversed. Like it, too, the veins are narrow, and the fluorspar is highly crystallized. It differs, however, in having some of the fluorite highly amber colored. The deposits worked have been partly detrital. For further details of deposits now being worked, see pp and . The Fluorspar is reported as running 96 to 98 per cent. calcium fluoride and to be low in silica content.

Colorado Districts.—In Colorado, fluorspar occurs, in any considerable quantity, only in what may be termed the Cripple Creek petrographic and metallographic province, though it occurs in small quantity also in San Miguel county in the southwestern part of the state, and elsewhere in less quantity, but usually with like associations. What is here called the Cripple Creek province extends practically due north and south for 150 miles from Boulder county on the north to Custer county on the south, inclusive; its width does not exceed 30 miles. In this province the rocks are gneisses or granites, (largely of Archæan and Algonkian age), with igneous intrusions varying from acid to basic (phonolites, andesites, etc.)

The ore minerals are in large part gold and silver tellurides, while the gangue is chiefly quartz and dark colored, usually purple, fluorite. Only those deposits which have shown the fluorspar concentrated to a considerable extent, have been worked for it. Openings at which such conditions existed on Bear Creek in Jefferson county and at Jamestown, on James Creek, in Boulder, such local concentrations are re-

* See also the Director's Report of Progress for the years 1904-'05.—C. J. N.

ported worked out. In Custer county, near Silver Cliff, a vein of unusual continuity is reported by Mr. Blackett, the operator.

Castle Dome District, Yuma County, Arizona.—Fluorspar occurs here white, pink, green and purple in silver-lead veins from a few inches to 7 feet or more in width. The pay streak is said to follow the fluorspar. No fluorspar has been sold from these mines since 1903, as the demand ceased, apparently due to discontinuance of the use of fluorspar in Portland cement manufacture by California plants. The fluorspar was sold at a good price, the best bringing \$11.50 per ton. Thousands of tons are reported as lying upon the dumps, and only such fluorspar is brought to the surface as is necessary to facilitate mining, and the remainder is used for gobbing in the mine.

Piedmont Region, Albermarle County, Virginia.—The principal vein is situated on the east side of the Blue Ridge mountains, at Faber Mills. According to Dr. T. L. Watson,* it strikes N. 45 to 50 degrees E, and dips 70-85 degrees N. W., and is 4 feet wide, and occurs in a region of metamorphic sedimentary rocks of possibly Cambrian or post-Cambrian age, traversed by diorite dikes paralleling the vein. The fluorspar quartz, through which the zinc blende and galena are distributed, occurs in lenses along the vein. Stringers of schist, such as form the country rock, occur through the vein, giving it a banded appearance. The vein is said to carry 17 per cent. fluorspar. Krom dry jigs are used in concentrating, and are reported as giving a 48 to 55 per cent. zinc product, containing about 5 per cent. fluorspar. This is not a satisfactory zinc separation. This is of interest, since the same process was tried by the Seacoast Mining Company, at Paducah, and proved even more inefficient for Kentucky-Illinois zinc-fluorspar ores.

General Occurrence and Associations.

Fluorspar generally accompanies three general types of deposits: (1), Tin deposits; (2), Gold telluride-quartz deposits; (3), Spathic lead-zinc deposits. All

* Lead and Zinc Deposits of Virginia, pp. 57, et seq.

three types result from after effects of igneous intrusions in varying degrees of intensity, the first representing the greatest, the others in descending order, from whence we have the three corresponding genetic types: (1), Pneumatolytic deposits, resulting from gaseous emanations and including some magmatic secretions and fumarolic deposits. (2), Pneumato-aqueous deposits, resulting both from gaseous emanations and thermal waters. (3), Thermo-aqueous deposits, resulting from heated waters. The occurrences of these three types increase in abundance from first to third, the spathic lead-zinc deposits being several times as abundant as deposits of the first and second types. The economic importance of the several type deposits, in the production of fluorspar, increases in like ratio. All the really large deposits belong to the spathic lead-zinc class, except occasional extreme examples of the first two types in which fluorspar happens to be the preponderant product. These several deposits occur both filling open cavities and as replacements of the adjacent rocks, according as the conditions are more favorable for one or the other. Likewise, they occur both as tabular deposits, filling vertical or inclined faults or fissures, as horizontal deposits along bedding planes, faults or replacing bedded strata, and filling stock works; hence, irregular in outline. All primary deposits carrying fluorspar fall in the classification already presented.

Fluorspar also occurs in two genetic types of secondary deposits: (1), Aqueous deposits (resulting from redeposition of meteorically dissolved primary deposits), inconsequential from an economic standpoint, and only of mineralogic interest, owing to a small amount of fluorspar dissolved through the agency of meteoric (surface) waters; (2), Detrital deposits, including gravel and placers resulting from mechanical disintegration of primary deposits.

Fluorspar is of wide-spread occurrence, though small in quantity, when compared with some other minerals. Using F. W. Clark's statements (fluorine content of earth's crust, .02 per cent., etc.) as a basis, we find there is roughly more than 145 times as much iron ore as fluorspar in the earth's crust.

Association With Tin Deposits.—"The most important ore-minerals of tin deposits are cassiterite, wolframite, (tungsten), native bismuth, arsenopyrite and lollingite, molybdenite and scheelite; more rarely stannite, bismuthinite, specular hematite, iron spar, chalcopyrite and other copper ores, magnetite, stolzite, lead tungstate), as well as the secondary minerals scorodite, pharmacosiderite and bismuth ochre. In the gangue, quartz and lithia-mica are most common. Orthoclase, gilbertite, topaz and its fibrous variety, pycnite, *fluorspar*, apatite, and tourmaline are also frequent. Beryl, herderite $\text{PO}_4\text{Ca}(\text{Be}(\text{OH},\text{F}))$ and triplite $\text{PO}(\text{Fe},\text{Mn})(\text{Fe},\text{Mn})$ are rarer. Tin veins occur associated with granites that carry lithia-bearing mica and cassiterite among their normal ingredients; sometimes their silicates also contain tin. A few deposits are found associated with acid eruptive rocks, rhyolites and trachytes. The lodes cut through the eruptive masses, as well as the other country rocks, the rocks showing a peculiar and characteristic alteration adjacent to the veins. By this alteration the feldspars have been destroyed and in their place quartz, lithia-mica, topaz and tinstone, and often tourmaline also have been deposited. This altered rock is called greisen when derived from granite, the alteration product of the other rocks having no special name, being simply called tin ore."—(The Nature of Ore Deposits, by Dr. Richard Beck, Translated and Revised by W. H. Weed, 1905.)

Deposits of the tin class occur in the United States, in the Black Hills of South Dakota, in the Gafney district in South Carolina, near Roanoke in Virginia, and near El Paso in Texas. In Alaska, fluorspar is found with the York tin deposits. The tungsten vein at Trumbull, Connecticut, and the silver-lead vein at Einstein mine, in Missouri, also belong to this class.

The large pure fluorspar lodes associated with quartz and an occasional addition of red feldspar and silvery-white mica, which, according to T. Valentine, occur in Argentina at San Roque in the province Cordova, are an end product or extreme example of the tin "formation,"* and the only deposits belonging to this type now worked for fluorspar.

* Beck-Weed, The Nature of Ore Deposits, 1905, p. 218.

A somewhat similar occurrence is that of a fluorspar vein in quartz at Westmoreland, New Hampshire.

The large deposit of cryolite with which a little fluorspar is associated at Ivituk, Greenland, is another type of end product of this type. An example of fumarolic deposits is that of the colorless octahedrons of fluorspar in Vesuvian lava.

Detrital deposits of this group, tinstone and fluorspar, are to be found in nearly every district where the primary deposits occur, but the greatest example, according to Dr. Beck, is found on Mt. Bischof in northwestern Tasmania.

Association With Gold Telluride-Quartz Deposits.—The ore minerals of this group consist mainly of native gold, gold and silver tellurides, and auriferous pyrites; to a small extent, gray copper, galena, sphalerite and stibnite. Fluorspar, usually purple, and quartz, usually intimately intermixed, are the chief gangue minerals.

The typical associated rocks are porphyritic granites and volcanic tuffs and breccias of phonolite, occasionally basalts.

Deposits of this type are found in the Cripple Creek and Telluride districts, Colorado; Judith Mountains and Little Rock Mountains districts, Montana; and Northern Black Hills district, South Dakota; while somewhat related is the King's Mountain district, North Carolina. The deposits of Boulder, Jefferson, San Miguel and Custer counties, in Colorado, while lacking tellurides, present most of the other features of this group and should be classed with it. Placer or gravel deposits are practically unknown in this class.

Association With Spathic Lead-Zinc Deposits.—Now we come to the, as has already been noted, most important as well as most abundant class of deposits with which fluorspar is associated and that from which nearly all of the commercial fluorspar is derived, or likely to be derived for many centuries to come.

The characteristics of this group may be summed up: Chief ore minerals galena and sphalerite, less frequently pyrite or chalcopyrite, again rarely copper ores may predominate; sometimes silver and gold content high; more frequently it is low. Gangue minerals, chiefly fluorspar, barite, calcite, and, to a greater or less extent, quartz. In these deposits, sometimes fluorite, sometimes barite predominates,

while transitions occur where the deposits show barite, fluorite, or calcite only. In districts where fluorspar is at all present, it is, however, rarely absent from any of the deposits. Analogous in a slight degree is the rare occurrence of fluorspar in quicksilver deposits, as at Idria, Austria, and in manganese deposits at Romaniche, France.

Typical associated minerals are those already mentioned as occurring in the Kentucky-Illinois district, while in addition the following are at times present in deposits of this class; Apophyllite, arsenopyrite, bornite; celestite, datolite, desmine, epidote, glance, gray copper, jasper, laumontite, natrolite, phrenite, siderite, tetrahedrite, witherite, etc.

While the wall rocks of such deposits are usually sedimentary rocks, in nearly all cases there are associated igneous rocks as intrusions in the sedimentary, while in a few instances they occur entirely within regions of igneous rocks. The only instances where no direct association with igneous rocks have been noted, are in the Central Kentucky and Central Tennessee districts, although near the first of these are the peridotite dikes of Elliott county, Kentucky.*

The Kentucky-Illinois, Castle Dome, Central Kentucky, and Central Tennessee districts which have been described in some detail above, the principal fluorspar districts of the United States, belong here. Also the deposits of the Southwest Virginia district and of the Piedmont region of the same State (only the latter, of the two, showing fluorspar in quantity), though in associations different from any of the previously mentioned localities. The Kentucky-Illinois, Central Kentucky and Central Tennessee districts furnish important detrital (gravel) deposits of this class.

In Mexico there are numerous deposits of this type, in which, however, the fluorspar, lead, zinc, and pyrite are intimately intermixed, of which the silver and gold-bearing lead deposits of Mapimi may be mentioned.

In Canada, fluorspar occurs in deposits transitional between the tin and spathic lead-zinc classes, inclining more to the latter, but not of economic importance as far as is known in the Ottawa, Nippissing and Thunder Bay districts, also in Richmond county, Nova Scotia.

* The Elliott county dikes are 60 to 70 miles distant from the nearest known deposits of fluorspar.—C. J. N.

In Europe there are many prominent districts with ores falling in this class. In Great Britain there are two districts, the largest of which lies on the border between Scotland and England, though largely in the latter, embracing Lanarkshire and Dumfriesshire in Scotland, Cumberland, Durham, Northumberland, Westmoreland and York. To the south lies, in north-central England, the Derby district.

The most important deposits in Germany, of this type, if their fluorspar production be considered, are the lodes of Neudorf-Harzgerode in Anhalt, the copper lodes of the Saxon Vogtland, and the barytic lead veins of Freiberg, Gersdorf, and the Mittweida and Oederan districts, Saxony. Less important fluorspar occurrences are those of Badenweiler in Baden, silver cobalt veins of the Annaberg field, Swartzenberg in Saxony, etc.

In Austria, the Bleiberg deposits carry fluorspar, while that mined in France comes from Haute Loire, near Anrouse. Workable deposits occur in Spain. In Sardinia, it occurs at Sarrabus. It also occurs in the lead-calcspar veins of Kongsberg, Norway.

In Australia, the Broken Hill silver-lead zinc deposits carry more or less fluorspar, and are of especial interest, owing to the flotation processes used there in concentrating the ores, which suggested a similar solution for the Kentucky-Illinois zinc-fluorspar separating problem.

List of Fluorspar Localities in the United States.

Fluorspar is found in 28 States and Territories of the United States, though in only twelve is the occurrence of more than mineralogic interest. In only five of the twelve has an attempt been made to mine it for market; in the remaining seven it is associated with ores of greater economic importance than itself. In the list of localities given, * * indicates shipments have been made; * found in some quantity; others of mineralogic interest only. The names in heavy type are those of counties.

ARIZONA.

Coconin: Colorado Plateau. **Yavapai:** Near Prescott.
****Yuma:** Castle Dome District.

CALIFORNIA.

Contra Costa: Mt. Diablo. **Mono:** Ferris Canon, in Sweet-water Mountains. **San Diego:** Palomer Mountains.

COLORADO.

****Boulder:** Jamestown. **Chaffee:** Mt. Antero. **Clear Creek:** Georgetown. ****Custer:** Silver Cliff. **Douglas:** Devil's Head. ***El Paso:** Elk Creek, N. E. base of St. Peter's Dome, near Cheyenne, Pike's Peak. **Gilpin:** Gregory District, Russell district. ****Jefferson:** On Bear Creek. **Park:** N. part of Hall's Valley. **San Juan:** Poughkeepsie gulch, in quartz veins. ***San Minguel:** Telluride district, (Deer Trail Basin, Bridal Veil Basin, and Canon Creek).

CONNECTICUT.

Fairfield: Long Hill, Trumbull. **Middlesex:** Middletown at Lead mine. **Litchfield:** Plymouth. **Windham:** Willimantic in a vein in gneiss and in a topaz vein.

ILLINOIS.

****Gallatin, Hardin, Pope, Saline:** Southern Illinois district.

KENTUCKY.

***Boyle, Franklin, Fayette, Jessamine, Mercer, Woodford,**
etc: Central Kentucky District.

****Caldwell, Christian, Crittenden, Livingston, Lyon,**
Trigg: Western Kentucky District.

MAINE.

Hancock: Blue Hill Bay (Long Island) in veins. **Oxford:**
Stoneham, Wilson.

MARYLAND.

Allegheney: Near Cumberland.

MASSACHUSETTS.

Hampshire: Southampton Lead mine.

MICHIGAN.

Alger, Alpena, Chippewa, Luce, Mackinac, Schoolcraft:
In sedimentary drift.

MINNESOTA.

St. Louis:

MISSOURI.

?Barry. Madison: Einstein Silver Mine, near Iron Mountain. **St. Louis:** Near St. Louis, in St. Louis limestone.

MONTANA.

***Fergus:** Judith Mountains. Little Rocky Mountains.

NEW HAMPSHIRE.

Carroll: Chatham, Jackson. ***Cheshire:** Westmoreland, in quartz vein. **Coos:** White Mountains. **Grafton:** Grafton.

NEW JERSEY.

Sussex: Andover Iron mine, Beemerville, Franklin Furnace and Sterling Hill, near Ogdensburg, in connection with the iron and zinc deposits. **Morris:** Hibernia.

NEW MEXICO.

***Grant:** Mimbrees Mts., near Silver City. Veins in limestone or shale. **Sierra:** Lake Valley, in limestone. **Socorra.**

NEW YORK.

Cayuga: Auburn. **Clinton:** Finch Ore Bed. **Essex:** Minerville. **Jefferson:** Adams, Alexandria (Muscolonge Lake), Antwerp, Theresa, **Lewis:** Lowville, Martinsburg. **Monroe:** Rochester. **Niagara:** Lockport, Niagara Falls. **Orange:** Amity, Edenville. **Onondaga:** Fayetteville, Maulins. **Putnam:** Brewster (Tilly Foster Iron mine). **St. Lawrence:** De Kalb, Fine, Gouverneur, Hammond, Macomb, Mineral Point, Morris-town, Rossie. **Warren:** Johnsburg.

NEVADA.

Esmerelda: Aurora.

NORTH CAROLINA.

Cleveland: King's Mountain. **Gaston:** Long Creek mine. **Madison:** Near Marshall. **Watauga:** Yancy, Ray's Mica Mine.

OHIO.

?Warren: Carlisle.

PENNSYLVANIA.

Cheshire: Newlin. **Chester.** **Franklin:** Lancaster Station. **Lebanon:** Cornwall. **Monroe:** Delaware Water Gap. **Philadelphia:** Frankfort, Falls of Schuylkill.

NORTH DAKOTA.

***Custer, Lawrence, Meade, Pennington:** Black Hills district.

TENNESSEE.

****Davidson, Smith, Trousdale, Wilson:** Central Tennessee district. **Carter:** Watauga Point.

TEXAS.

Llano: At Barringer's mine, 5 m. S. of Bluffton.

UTAH.

Salt Lake: Park City (Woodside mine).

VERMONT.

Windham: Putney.

VIRGINIA.

Albermarle: Fabers. **Amelia:** Near Amelia, C. H., in mica mines, green variety, chlorophane. **Nelson:** Near Fawbers. **Rockbridge:** On Irish Creek. **Shenandoah:** Near Woodstock. **Smyth:** McCarter place in Rye Valley. **Wythe:** Cedar Springs.

WEST VIRGINIA.

Jefferson: Shepherdstown.

CHAPTER IV.

PROSPECTING AND MINING METHODS.

Suggestions for Prospecting in Western Kentucky.

Barring the location of ore in place at the surface of a tract of land that is to be prospected, the question arises what shall be looked for to determine whether it is worthy of expending money upon it for prospecting.

First, its location in a general way should be considered,—whether it lies in proximity to any mapped lode and just what its relations are to mines or prospects on adjacent tracts. Next, the character of the surface rocks should be considered and their geology determined. The most favorable location for faults and veins is along the borders of fault blocks, such as are shown on the geological maps published. By a fault block is meant a portion of rock strata bounded by faults. Beyond 1,000 feet from the borders, the chances are usually poor. With these general conditions known, we are ready to look into the more specific work of vein and fault location.

The criteria and methods used by the writer in locating faults and veins in the Kentucky-Illinois district, will here be briefly discussed. They have been discussed in detail by the writer in the report on Livingston County.

By faulting is understood the slipping past each other of two rock formations, either vertically, diagonally or horizontally, after the original formations or strata have been fractured.

CONDITIONS RESULTING FROM FAULTING.

Three general conditions result from faulting:

(1). Rocks are found in juxtaposition that are absolutely unlike each other in composition, and general appearance, as, for example, sandstones and limestones.

(2). Rocks of like character, but of different age, occur in apposition and are to be distinguished, such difference being distinguished by characteristic sets of fossils different in rocks on each side of the fault; or by a characteristic set of fossils on one side, and their absence on the other, or a

total absence of fossils on the one side. These conditions are somewhat difficult for the general person to determine. The most important fossils are the large reed-like aggregates of coral of the St. Louis; the smaller reed-like corals of the Ste. Genevieve; the screw-like fossils of the Chester rocks, etc.

(3). Different formations of like general character, as of limestone, but having unlike special features as oolitic texture, fine grained, etc., occur opposite each other.

While in some instances these general conditions are readily recognized, in most cases they are not. It becomes necessary in the latter case to determine the presence of one or more of the special conditions now to be named, that occur opposed to each other, before it is possible to decide that a fault or vein is present.

Such special conditions depend on (1) Original character of the rock; (2) Physical changes induced by faulting; (3) Chemical changes; (4) Effect of faulting on underground circulation.

Differences depending upon original character of the rock that are to be looked for are:

(a) Differential fossil contents.

(b) Differential texture, as fine grained and oolite limestones, cherty and non-cherty limestones, fine grained and conglomerate sandstones, etc.

(c) Differential mineral constituents, as mica in one sandstone and not in another; this is rarely of benefit here.

(d) Differential lamination and bedding planes, as massive sandstone opposing slaty sandstone, heavy bedded and shaly limestone, etc.

Physical changes that result from faulting are:

(a) Differential shearage; results when a rock is brittle on one side and elastic on the other, that on the brittle side cracking into (a) angular fragments, a condition termed brecciation; (b) narrow, vertical or slightly inclined sheets, termed sheeting; (c) the cracking of the rocks into angular blocks on a small scale, termed jointing. Brecciation and sheeting are often reliable factors in locating veins in this district, while jointing is not since it occurs here too generally, though it is of value in determining the strike of faults in its vicinity. Other shearage effects are gouge, resulting from the grinding to clay of a part of the rock on one side; slickensiding, where friction

has made the rock on either side slick; striæ, or grooving, usually accompanying slickensiding, occasioned by friction of the rocks in slipping past each other.

(b) Differential strata dips, as when the rocks on one side are horizontal, and on the opposite are inclined. Care must be taken, in using this, not to consider the dips of boulders, as of broken down Rosiclair sandstone.

(c) Differential alignment of strata; this is notable where fault scarps, instead of continuing in a straight line, occur in an irregular line or in steps, termed *en echelon*. Such irregularities result from cross-faulting or heave.

(d) Differential disintegration, as when one rock is easily eroded, while the other remains with a bold face or scarp, as soft sandstone and quartzite the latter remaining as an erosion scarp, while the soft sandstone wears easily away. A great many, perhaps the majority, of the ridges of the district are erosion scarps. The ridges along the Excelsior or Marion fault zone, extending from Marion to Pinckneyville, have marked examples of such scarps on both sides of the ridges.

(e) Differential elevation of strata. This results in fault scarps. Such are seldom present in the district, such scarps as are seen being erosion scarps; the first being those formed originally by faulting; the latter, the result of wearing down of one of the walls by erosion.

A number of differences result from chemical changes that are quite important.

(a) Differential cementation. This consists in the deposition of silica, iron oxides or calcium carbonate, etc., from circulating ground waters, making the rock harder and more compact. Deposition of silica changes soft sandstone to quartzite; of calcium carbonate, changes limestone to marble, etc. An attendant result at times is the bleaching of the quartzite, by the same waters robbing the sandstone of iron oxides. Quartzite ledges occur up to 200 feet from the faults. They form one of the best criterions we have. However, where an entire bed of sandstone, say over a mile or more in area, is quartzose, such quartzite can not be used in locating a fault. Certain quartz masses occur in the St. Louis, which simulate quartzite in appearance, and care must be taken not to mistake them for it. When

limestone is affected by silicification, it is altered to jasperoid, a rock not unlike chert, somewhat porous, and showing under a magnifier minute six-sided, double pointed quartz crystals; such a rock is a sure fault criterion. Cherts occur also silicified.

(b) Differential leaching. Ground waters effect leaching and subsequent softening of the rocks. Calcareous sandstone, as the Rosiclare, changes from a green, compact rock to a soft porous one on the leaching of the calcium carbonate. Broken down masses are usually found, but seldom indicate a fault. A leaching condition of importance, however, is where limestone occurs honeycombed with small pores where zinc sulphide has been leached out; large honeycombed limestone is also of importance sometimes where calcite has been leached out.

(c) Differential dissolution and (d) Differential disintegration. In the former, complete dissolution takes place, giving us a valley or plain opposite a land mass not so affected, forming a ridge or plateau. This is when a pure limestone is dissolved. In the second case, leaching goes so far as to break the rock into fragments or grains. Again, where red clay and chert result from decomposition of silicious limestones. If they oppose limestones not broken down, a fault is indicated. Sinkholes, caverns, etc., result from dissolution of limestone along a joint plane. These are only of value in determining the location of veins when a number occur along a practically straight line. Then they should be closely examined, and analysis made of the filling. Surface dissolution may be effected by rivers, creeks, and smaller streams, these cutting their channels in the rock along a fault or on that side which has the most soluble rock; hence, they are often an aid in locating a fault. For example, Deer Creek follows pretty well the fault zone of that name.

(e) Differential residuals. These depend somewhat on the two previous. An example is red clay opposed to red clay with chert nodules; many cherts in clay opposite clay with fewer cherts; angular cherts opposed to nodular cherts; fossils in clay, etc.

Faulting affects underground circulation, giving us several special conditions. Foremost among these are springs of either fresh or mineral water, several occurring along a

fairly straight line, as along the Columbia lode. Discoloration of the soils, efflorescences and marked vegetation along a narrow zone also are a weak criterion in this district in locating a fault.

APPLICATION OF EVIDENCES AFFORDED AS TO FAULTS.

Systematic application of foregoing criteria:

It is seldom that any of the foregoing criteria afford evidence so plain that it singly may be depended upon to determine the presence of a fault, though some of them present larger values in this respect than do others. Usually, features of two or three used jointly will decide. In looking over an area, evidences of as many as possible should be looked for, and notes made concerning the presence or absence of each, together with recording the dip and strike of strata, and the strikes of all joint planes available for measurement.

If the evidences are very slight and insufficient to decide as to the presence of a fault or shear zone, or if they are sufficiently definite to determine the presence of a fault, but its exact location too indefinite to locate a cross-cut or a shaft, resort is to be had to systematic survey.

Such a survey should consist of the location and elevation of all the more important points. This may be accomplished with a compass and barometer if more precise instruments are not available. By important points is meant mainly rock outcrops which might throw light upon the structure of the area. Barring the presence of these, evidences of criteria above discussed are likewise located and elevated. Then a plat may be made. Elevations are compared, the bearing of the notes gathered on criteria considered, use made of the rule for strike sets presented below where necessary. All these things being considered in the study of the plat, the geological relations and structure, for the most part, will be readily discernible.

Points that still appear in the shadow, may oftentimes be brought to light by the construction of cross and longitudinal sections, such as accompany the report. For this, it is necessary to plat the elevations at the distances apart as they occur on the map, on a line of all important points, and a vertical section of the strata sketched in. Sections at right angles to those first made often assist in bringing out new

points or correcting errors that have crept in.

Having determined the location of fault or vein on a tract, we should next consider whether it is worthy of being prospected. Generally speaking, preference should be given to those tracts that show faults or veins with one of the important and preferably lower limestones of the Mississippian series,—that is to say, limestones below the Birdsville formation, for one or both walls. While a number of ore deposits have been worked which have Birdsville or higher rocks for both walls, the heavy bedded sandstones which such formations contain, make it unlikely that good ore bodies will be found until a depth of from 200 to 500 feet is reached; hence, the inadvisability of prospecting such faults in this district at present, where so many faults occur with the conditions more favorable for attaining ore at reasonable depths.

A fault showing favorable conditions being selected, a point along it should be chosen with the following conditions taken into consideration: (1) The point at which the faulting conditions are most marked. (2) The natural advantages offered at any point for the suitable location of a shaft, such as a good dump, location for plant, least hindrance from surface waters, etc. In prospecting, the writer has found (1) the most important, and would advise it as the primary consideration in prospecting, leaving (2) the location of a permanent or working shaft as the prime consideration after the fault has been tested. In all prospecting, working from known to unknown is the wisest policy, and what has just been advised accords with this.

PROSPECTING THE FAULTS.

Work should always be begun in the limestone side, where sandstone or quartzite forms the contiguous wall. It should be begun in the shale side if shale is opposed either to limestone or sandstone; except when the limestone that forms the contiguous wall is reduced to its residuals, in which case it is cheaper to work in the limestone side than in the shale side. Care should be taken not to be led, by decoy debris rolled down from the opposite and higher wall, to locate a prospect cross-cut too far on the limestone side of a fault. For prospecting a surface cross-cut three feet wide usually answers. Such cross-cuts may be made six feet in length, and placed six feet apart.

If the first of such cross-cuts is sunk a sufficient depth to pierce surface debris, and shows no evidence of the fault, cut another six feet distant in the direction of the rock of opposite kind to that found in the cross-cut. And, in this manner, a number may be cut till the opposite rock or its residuals (what remains from its decay) may be found. If the last shows the opposite rock, but not the fault, then a cut must be made between it and the nearest cut showing the other rock. The location of the vein or fault plane being now definitely known, sinking may be pursued a moderate depth, say 50 feet down such plane, the prospect shaft being preferably sloped to follow the dip. If no ore is found, a drift or drifts may be run along the strike. Barring the location of spar or ore at such opening, two similar openings may be made in each direction on the fault, 150 feet distant. This will, in most cases, fully test a fault.

Prospecting by vertically or slightly inclined drilling has so far proven impracticable in this district, this largely because of the close approach to verticality of the faults, so that even if a number of holes are put down, each and all might miss the fault a few feet or a few inches, even. Hence, shafting with proper cross-cutting, either by ordinary methods or horizontal core drilling, is the most practical means to employ. In prospecting, at first one man may be employed at a cross-cut and then two where deep enough to use light bucket with windlass. Small shafts, 4x5 or 4x6 in the clear, are used and the crew generally consists of four, one of whom acts as a timekeeper and foreman, two men being employed at the windlass and two in the ground. Sometimes light buckets are used and only one man is used at the windlass. A crew of four should raise on an average of 125 buckets the size of a half beer barrel per ton ten hours when not timbering. Where any depth beyond 50 feet is to be attained, a common horse whim may be cheaply employed. If more rapid developments are desired, or considerable water has been encountered, or any considerable prospecting is to be done, it is most economical to use a prospecting rig. Such a rig should consist of a 12 to 16 horse-power portable boiler, with 6 to 8 horse-power hoisting engine attached, and a good but simple sinking pump, with at least a 2-inch discharge. Prospecting can be carried on with such an outfit with the use of three

men, a like number being required where whim is used. While some of the deposits are put on a good basis in a few months, oftener as much as a year is required to put in a fair state of development.

LOCATING PARALLEL AND OTHER FAULTS.

Besides the master fault, complementary parallels or sub-parallel, and cross, or intersecting, faults are to be located, since frequently, where the master fault is barren or nearly so, one of these may hold the best ore, and vice versa; or, one may carry flourspar, and the others lead and zinc, and vice versa; from which it will be seen that cross-cutting to locate such complementary faults is always advisable, and it is impossible to do too much cross-cutting, if of the proper kind. Cross-cutting should preferably be done in the limestone wall if the vein have such rock on one side, while brecciated or sheeted quartzite should be considered next favorable.

Where parallels or sub-parallel are indicated, cross-cutting may be done at right angles, the direction appearing most favorable, in order to cut such faults at the least expense. However, if cross or intersecting veins are also sought for, another method becomes more practicable, of which, more anon.

The writer has found that it is possible to determine the approximate strike or direction of complementary cross or intersecting faults by a rather simple rule, which he has worked out.*

This rule depends upon the theory, substantiated by experience, that fractures resulting from tension stresses form rather constant angles with each other in multiples of 30 degrees, while those from compression stresses form constant angles with each other in multiples of 35 degrees. In this district the majority of fractures appear dependent on tension stresses, and the rule as formulated for them is as follows:

If the known strike is northwest, add 60, 90 and 120 degrees to it in an easterly direction around the circle, and the resulting strikes will be the corresponding complements of the known strike. If the known strike is northeast, add 30 and 60 degrees in an easterly direction around the circle to,

* The Classification of Faults and Fractures into Series and Sets. Eng. & Min. JI., Vol. LXXXI, No 12, 1906, p. 553-554.

and subtract 60 degrees in a westerly direction around the circle from it, and the resulting strikes will be the corresponding complements of the known strike.

The amount of variation may in some cases amount to as much as 10 degrees, though in most cases it will be less than 5 degrees. Where faults are found in a section that do not group themselves into one of these sets within the limits named, there are faults belonging to more than one set present, and the complements of the two or more sets are then to be sought. Often, only two members of a set are obtained, though usually a third is present, and less often a fourth. In the Kentucky-Illinois district, a northeast and a northwest, with usually one of the other two are found, depending on what part of the district one is in. For example, in the Columbia mines section, Series B and F, Set 1, are most frequent.

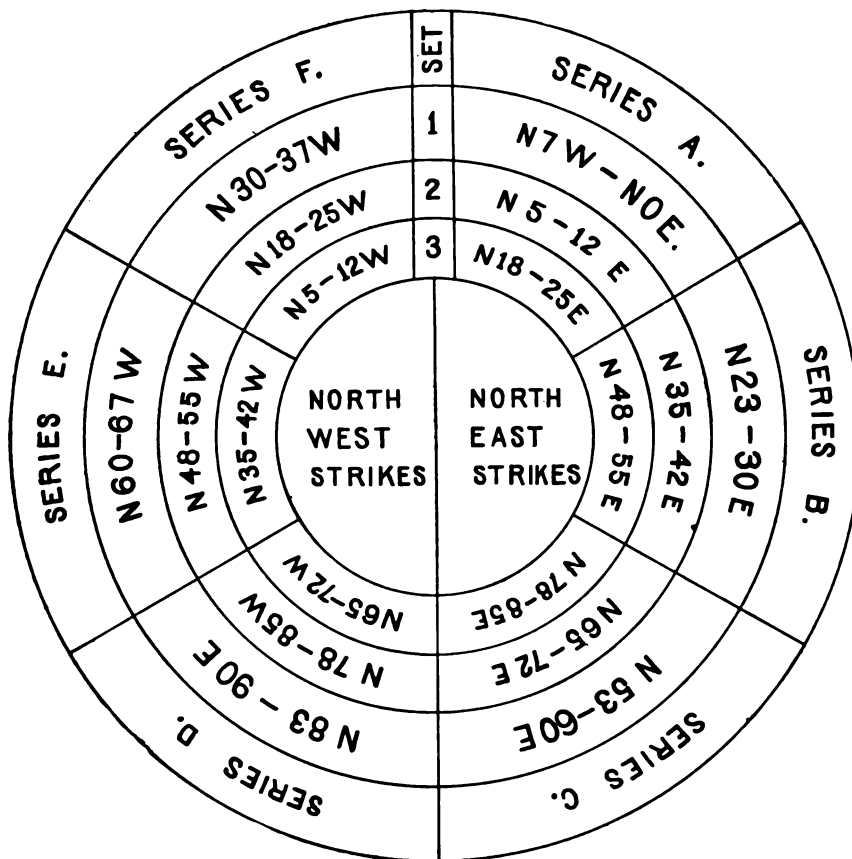
In order that the rule may be readily applied to the Western Kentucky district, the writer has prepared the diagram given on the following page, which presents the strikes most common in the district with their corresponding complements. If the table below given is used in connection with this, it becomes an easy matter to determine what the complementary strikes in any case are by mere inspection:

If Known Strike Belongs in:	Complementary Strikes are:
Series A.	Series E. B. C.
" B.	" F. C. D.
" C.	" A. D. E.
" D.	" F. A. B.
" E.	" A. B. C.
" F.	" B. C. D.

For example, if the original strike is N. 27 E, it falls in Set 1, Series B of the diagram. In the above table, we find the complement will be in Series F, C, and D; therefore, following the circle of Set 1, we find the complements should lie between N. 30-37 W., N. 53-60 E., and N. 83-90 E.

With the approximate strike of the complements known, all surface and underground conditions capable of being learned, should be carefully considered, and

from these determine in what direction from the shaft cross-cutting would be most advisable, and also which of the complementary strikes comes nearest fulfilling the known conditions. One is then ready to cross-cut at an angle of 30 degrees with the known strike, in the direction of such favorable conditions. If both parallel



or sub-parallel and cross or intersecting faults are anticipated, cross-cutting at an angle of 30 degrees with the known strike will quickest cut either or all of such faults. If there are no favorable conditions suggestive as in which direction to cross-cut first, then it is immaterial in which direction the cross-cut may be first made, but any and all should be run at

an angle of 30 degrees from the known strike in such instances.

The question next arises, to what extent is the cross-cutting to be carried? From the map work, it is learned that the complementary faults are to be expected for a distance of 1,000 feet; in some instances even more on either side of master faults, such as bound the fault blocks. The nearer the master fault, the better the chances. It should be carried at least two to three hundred feet from the master fault. Surface search should be made for the larger complementaries of secondaries, and these should be investigated with their complements in like manner.

Where evidence of a fracture or fault exists with the direction indeterminable, this may be approximately obtained thus: Determine the bearings of joints of rock outcrops in the vicinity. The member having a strike most nearly coincident with that of the major fractures of that section will most probably approach that of the fracture, whose strike is to be determined; or, where conditions suggest a different strike, it will approach that of the one of the three corresponding members of a set (constructed as indicated above) which comes nearest filling the given conditions.

Post-Development Work.—A word about this will not be out of place here. Oftimes, an ore shoot is worked out and a property abandoned. This is entirely inexcusable in the Western Kentucky district, where the lodes have ore shoots, at more or less regular intervals, along their entire course, also in depth.

In the Joplin district, where it is far more difficult to locate an ore shoot after the first has been worked out, there are fabulous sums made by persons having courage to work an abandoned property. But we need not go so far from "home." The original Asbridge shaft, which opened one of the largest gravel flourspar shoots yet found, was first sunk only 40 feet with nothing found, while, later, another company stepped in, sunk it deeper and cross-cut, with highly satisfactory results. If pinches are met, drive through them while getting ore from other parts of the mine, to help pay for it. Do not wait till all the ore is mined out, for, as surely as this is done the company will become discouraged, and the

"ill wind" will blow a new company on to a good foundation.

The methods given for primary prospecting work, are, for the most part, applicable to post-development work. The inexhaustibility of the fluorspar lodes has recently been proven on the oldest properties. The pitch of the ore shoots will, in most instances, correspond with the pitch of the predominant slickenslided grooves in the ore, resultant from secondary faulting. The dip of such grooves does not necessarily correspond to the grooving on the walls due to primary faulting previous to ore deposition; hence, the grooving of the walls cannot be used for this purpose. These facts may often be of value in assisting in determining approximate distance to an ore shoot on a lower level, etc.

Mining and Timbering Methods in Kentucky-Illinois District.

Shafting, Etc.—Shafts vary from 3½x5 to 8x20 feet in size. The most common sizes are 4x6, 5x8, 5x9, and 6x8 feet (in clear of timbers). For prospecting, where shallow depths only are to be attained, shafts 4x5 feet, and where a depth of not less than 100 feet is to be sunk, 5x8 feet, are the most practical and economical sizes. A 5x8 feet shaft will answer all purposes in sinking several hundred feet and for tonnages not exceeding 60 tons per 10 hours. A shaft of this size allows for two compartments, a 4x5 feet bucket-way, and a 3 feet 5 inches by 5 feet ladder, pump and pipe-way. Where a double hoistway is desirable 5x12 will best answer. Both vertical and inclined shafts are in use. The inclines dip from 60 to 72 degrees. Many of the shafts follow the sinuosity of the vein, hence are irregularly inclined, but closely approach the vertical, dipping on an average of 80 to 85 degrees. Where vertical shafts are sunk, cross-cuts are run to intersect the vein, where the vein has left the shaft. The cross-cuts are managed similar to the drifts. At the old Keystone shaft, the shaft was sunk vertical to the cross-cut at 100 feet depth, then in order to follow the vein about an 8-foot offset was made, and the shaft from thence irregularly inclined; the iron was managed by rollers at the top of the offset, then pulled along the cross-cut by a tubman and finally hoisted through the vertical section.

The shafts are timbered usually with white oak, but where necessary, black or spanish oaks are employed. Pen

timbers, usually sawed or hewn, vary from 6x6 inches to 12x14 inches; 6x8 inch timbers being commonly used for small shafts, 8x10 inches for larger ones. For the prospect or contract shafts sometimes bark-bearing logs are used. The widest side is usually horizontal. The timbers are dapped either half and half or better one-third each; occasionally more elaborate mortising is practiced, as cutting an extra dap, 1 inch and vertical, etc. The sets are placed 4 to 5 feet apart. For lagging from 1 to 3 inches plank was used, usually 1½ inches for the smaller shafts, and 2 inches for the larger ones. The lagging is at times placed end to end so that the union falls back of the pen-timbers, but the safer way is where the lagging is lapped about 6 inches; 9 feet lagging is used in the former and 10 feet in the latter. Wedge-shaped keys are used, made from 2x4-inch oak.

Bridge trees of 2x4 inches oak are sometimes spiked to the lagging above each set of pen-timbers so as to prevent the slipping down of the lagging. When such are used, the keys are placed between the two lapping sets of lagging; in other instances the keys are sometimes placed between the lagging and the pen-timbers.

For hangers, a 2x4 inches and 2x6 inches plank is used, placed in each corner so as to form a right angle, and spiked with 40 or 60 penny nails. More rarely, as at the Memphis incline, iron hangers have been used. For stulls or corner posts, to support rigidly the pen-timbers, round bark-bearing posts, 5 to 8 inches in diameter, are commonly used; if of sawed lumber, 5x5 inches to 8x8 inches are used, though the first of these is sufficiently large. For buntions or spreaders 6x6 inches timbers are used most frequently; sometimes 4x6 inches timbers. These are dapped from 4 to 4½ inches, the projection resting upon the pen-timbers, where the pen-timbers are not dapped; again, wedge-shaped daps are made 1 inch in the pen-timbers and the buntions cut to fit the dap. The ladder-way is partitioned off solidly from the bucket-way by means of one-inch plank nailed in the bucket-way to the buntions. The remainder of the bucket-way may be lined with 1x4 inches plank placed 4 inches apart, the most economical as well as the safest method, since any leaks or breaks in timbering may

be more readily detected; more rarely, 1-inch plank is used to line the bucket-way solid.

Cribbing is indulged in to some extent. For this 4x10 and 6x10 inches timbers have been used laid flat and dapped either half and half or so as to permit about an inch space between them. In the corner a triangular hanger is spiked on. Prospect shafts have been cribbed with 2x4's laid flat and spiked on each other. Inch plank nailed in the corners was the only thing used to prevent the pen from closing in; hence, if the ground is any way loose such shafts are unsafe; in fact, they are undesirable under any condition in West Kentucky. In a few instances another undesirable method was employed; 2-inch lagging was used placed edge to edge with the 2 inches edge horizontal, for cribbing, and dapped half and half and either simply inch or two inches plank was used for corner boards; in one instance an air shaft was so timbered and 2x4 inches plank for spreaders was placed criss-cross, so as to hold the walls apart.

Mention of a singular method of retimbering noted at one of the mines will not be out of place: The old timbers and lagging were not removed, but reinforced thus: 2-inch lagging was cut so as to just fit between the old timbers and placed against the old lagging; 6x6 inches timbers were dapped half and half, and a set placed just on top and just below each old set of 6x8 timbers. New stulls and new hangers were put in. Buntons 6x6 inches were drapped 4½ inches, leaving 1½ inches to rest on the timbers and 4½ inches to catch the lateral strain, and the shaft was re-lined with 1x4 inches plank placed 4 to 5 inches apart.

The majority of the ladders are vertical, more rarely they are inclined in 16 feet lengths and reversed-inclined every other one. The ladders are made of 1x4 or 2x4 inches plank nailed to one side of one of the hangers and 1x3 inches plank is nailed across for rungs. Sometimes the rungs are mortised on. A few round rung ladders occur. The ladder ends are either spliced or overlapped. At the Evening Star, a stairway 2 feet wide alternately inclined, in 12 foot lengths, is used.

Drilling and Blasting.—Steam and air rock drills are in use; also air hammer drills (both the heavy sinking type

and light drifting or stoping type), and hand drills. For the machine rock drills X and I bits are commonly employed, the former in most rock and spar; the latter only in drilling quartzite, when they are made quite blunt. For the air hammer drill six-pointed, star-shaped, hollow bits are employed. For hand drills I bits only are used. Three-quarters to 1-inch steels are used, while the bits vary from $\frac{3}{8}$ to $1\frac{1}{2}$ inches across. In the matter of tempering bits the practice varies. The loss from wear of drills is usually very small, some mines not losing a foot a year. At the Memphis mines, they temper the six-point star-shaped air hammer $\frac{3}{8}$ -inch steel drill bits a dark blue for fluorspar and straw for the hard rock. Such points are sharpened as the X bits and will stand a week in fluorspar, while their length of use in rock is erratic. The losses of steel from 40 bits is said not to exceed 1 foot in a year.

At Fairview, in drilling spar, hand drills are now commonly employed and their bits are sharp edged tempered straw, and are said to last three shifts. For air drilling machine drills, X shaped bits are not tempered but chilled immediately from a red heat. These do not stand well in rock, and become easily jagged.

In tempering air drill X bits at the Ada Florence, they permit the blue to just begin for quartzite and to go beyond the dark blue for limestone. Steam drills are run at 125 lbs., air drills at 100 lbs. pressure.

At the St. John mines the hand drill bits are tempered bronze, nearly straw, for solid spar.

In sinking, the first 50 feet depth requires ordinarily but little blasting. The dirt is easily handled by pick and shovel; sometimes there is little to 100 feet depth.

Light shooting and shallow holes have been rather the rule; that is to say, holes usually less than $3\frac{1}{2}$ feet deep, seldom 4 to 6 feet, and with charges of from $\frac{1}{2}$ to 9 sticks, of 40 or 60 per cent. nitroglycerine $\frac{3}{8}$ inch to 1 inch dynamite sticks. Light shooting is necessary in fluorspar, otherwise it breaks too fine; for the same reason it appears undesirable to use dynamite stronger than 40 per cent. Little regularity or system is used by the mines ordinarily in breaking the ground. If one of the walls is not free to shoot to in the shaft, a break is most often made at one end, rather than in the center.

For hand blasting double and triple tape is employed. The majority of blasting is, however, done with battery, small sized batteries being used.

The cost of dynamite, caps, fuse, etc., is approximately 15 cents per foot of dynamite used.

In fluorspar mining the use of light air hammer drills results in greater economy than in any of the other methods. In rock, light drills of this character are not so satisfactory; in oolite, a common limestone to be drilled, such drills make only one foot in ten minutes, while in drilling fluorspar a three feet hole can be put in in that time. While the use of these drills is increasing and many small compressors are being installed, they are not used as largely as they should be, and even mines that have large compressors and rock drills, use hand drills for breaking spar when they could use the hammer drill to much better advantage. While the first cost of the hammer drill is small compared with rock drills, being about one-third, the cost for repairs is greater, and they are short lived. Another advantage of the hammer air drill is that one can blast so much oftener than in the other way.

Cost of Sinking.—The cost of sinking varies according to the part of the field, diligence of miners and rock sunk in. Shafts have been sunk in some parts of the district on contract 4x6 or 5x8 feet, timber to be supplied by company, for \$2.50 to \$3.00 for first fifty and sometimes 75 feet; for first 100 feet from \$3.00 to \$5.00 per foot. Beyond this depth the cost increases materially. The cost of sinking shafts the first 100 feet varies from \$3.00 to \$30.00 per foot. In sinking from below 100 feet and from that to 300 feet the costs vary from \$12.00 to \$80.00 per foot.

One large company reports the cost of sinking in soft ground at \$5.00 to \$12.00 per foot. With rock drills they report sinking in hard ground to cost \$15.00 to \$30.00 per foot. The writer had one shaft sunk where there was easy break and ore most of the way at a cost of \$2.59 per foot, (making no deduction for ore recovered) for 58 feet from surface, exclusive of timbering, the shaft being 8x12 on the outside, and reduced after the first 35 feet to 7x9.

Sinking in limestone and ore in a 7x9 shaft cost in one case

\$15.00 per foot using steam drills. Sinking in limestone has cost up to \$30.00 per foot, in a small shaft by hand drills where no break was present.

A shaft was sunk in spar, zinc and rock, with vein narrow but oxidized, with water level at 15 feet, at \$2.00 per foot on contract for 25 feet. The two contractors, outside of their own labor, were only at an expense of \$5.50, including the wages of one hand at 75 cents per day, and the shaft was sunk and timbered the 25 feet in 7 days.

At one shaft below a depth of 50 feet, the best record was made that the writer has learned of in the district, 2 feet being sunk per 9 hours, exclusive of timbering. The shaft was about 6x6 feet and a shot placed 1 foot from each corner inclined toward the corner 1 foot in four feet, the depth of the holes, and a 4 feet hole placed vertically in the center and fired first. This gave some break for the other holes which always pulled the corners. The cost was less than \$5.00 per foot, exclusive of timbering. Sinking in quartzite breccia cost from \$11.00 to \$40.00 per foot within 100 feet of the surface.

In a 6x8 feet shaft with a break, limestone and calcite on one side and quartzite on the other, narrow vein, they sunk about 11 inches per day; exclusive of timbering cost was near \$10.00 per foot, using air drills. In sinking a 5x9 shaft through mud and chert 14 feet, including timbering with four men, hand labor exclusively, they sunk at the rate of 7 inches per 10 hours. A shaft 82 feet deep, day labor, cost \$4.55 per foot, 4x6 feet outside, using 2-inch lagging for cribbing, and a horse whim for hoisting.

In one section, shafts on contract, everything included (all timbering except casing), were sunk the first 75 feet for \$4.25 per foot, using a whim and partly in soft ground. In the same section 100 feet shafts are sunk often at \$5.00 per foot.

The cost of sinking in partly soft ground, limestone and spar for 100 feet was on an average in one case \$7.00, the lower part costing \$10.00 per foot.

One shaft 8x12 feet cost \$40.00 per foot for sinking in quartzite, ore and limestone on contract, exclusive of timbering

and hoisting; this had a great deal of surface water raining in on the men, a matter which might have been remedied by making a cement gutter around the shaft just below where most of the water comes in, and guiding the water to a suitable point from which it may be pumped out.

Sinking in limestone, calc and fluorspar below 150 feet depth cost in one instance, in an 8x8 feet shaft, \$20.13 per foot day labor, sinking $7\frac{1}{2}$ inches per day.

One of the shafts cost \$80.00 per foot, this in limestone and ore below 150 feet. But these prices are exceptional. One shaft in ore and rock below 200 feet depth, 12x12 feet on outside.

The cost of sinking with steam drill in limestone breccia cemented with ore was \$10.00 per foot in an 8x8 shaft below 200 feet using a steam drill, with not a great deal of water to bother.

Drifting and Stopping.—The drifts are run along the narrow veins the full width, and where too narrow for car or flat with bucket, they are made four feet in clear. Entry sets are often lower than other parts of the drifts where properly they should be higher. This results from no provision being made when shaft is sunk in placing sets at proper distance apart where drifts are to be started.

Timbers with bark on are largely used in the smaller mines and most of the large ones. These are usually over 6 inches in diameter. The posts are set on either side on a 2-inch dap in the mud sill, while at the top a $1\frac{1}{2}$ to 2 inches, dap on both cap and side of posts. Sometimes the posts are slightly inclined toward each other, more often they are put in vertically. For hangers or tie pieces 1x4 or 2x4 inches plank are used. For lagging $1\frac{1}{2}$ to 2 inches, seldom 1 inch plank. Rarely small poles 3 inches in diameter are used for lagging. The same laps, etc., as used in sinking are here used. The timbers are placed 4 to 6 feet apart. For horizontal hangers 1 to 2 inches plank is used.

In wider deposits, where the walls are solid, heavy stull timbers are used, hitched or wedged between the walls. Some of these are over 30 feet in length, and 12 to 20 inches in diameter, though most are 3 inches or less. Where one wall is shale and the other limestone dapped posts are used to

support the stull timbers on the shale side, while they rest on hitches in the limestone side. In the wider gravel deposits where the walls are not in sight, they begin the same as for a small drift, and then widen out by running another set. Eighteen inches tracks are commonly used in the drifts. These are ordinarily of 8 or 12 lb. sometimes 16 lb., rails. Sometimes for light trucks and bucket, 2x4 inches oak planks are made use of for rails. Both light trucks and bucket and steel cars are in use.

Drifting with one man with air hammer drill costs \$3.50 to \$4.00 in ore or rock; for hand work from \$4.00 to \$8.00. In soft ground it costs from \$2.00 to \$4.00 per foot. The average cost of drilling is probably not much in excess of \$4.00 per foot.

In a mine having a large vein, they make 7 to 8 feet in a double shift, four men driving 8 feet wide.

Both underhand and overhand stoping are indulged in, some of the mines using one and some the other, a few using both methods, preferably the latter, which is the cheapest. The method to be used depends largely on depth of shaft. Necessity of securing mineral before time can be taken to sink shaft sufficiently for a sufficient head for overhand stoping makes the underhand method in some cases the most expedient. The drifts are in most cases placed too close together, usually thirty feet apart, in one case 18 feet only, and considerable extra expense is thus involved; placing them further apart, say a maximum of 100 feet, would prove economical. At one large mine the ore of the stope is shot down on round timbers 6 to 8 inches in diameter supported by 14-inch to 20-inch posts and caps. Every 75 or 100 feet, hoppers are placed above the track. These are in the shape of a truncated inverted square pyramid, and have a drop slide door. These hold 25 tons or so, and the ore is let into the cars practically automatically. In the larger veins it is customary, where possible, to leave the leaner portions of the vein in place, but only a small amount of culling is ever done in the mine. In drifting and stoping in fluorspar in the upper parts of the veins, 3 feet holes are put in mud seams, wherever possible. But few winzes or raises are in use. In timbering large gravel veins sets are run, as in drifting, along side of

each other, post against post, and ends of cap timbers contiguous. For mud sills 1½-inch plank is used, in some instances; in others a regular sized timber. For hangers or stringers 1½-inch plank is used. After the drift has been run the spar is taken out by overhand stoping, being picked down, two sets along the course of the vein at a time and a level 6 feet in height carried back as far as the drift goes. In doing this the cap lagging of the drift is removed and used again above. After the level has been run, another set is taken out above it, and so on until the stope is carried its full height. At one of the mines, 12-foot timbers are used instead of 6-foot ones, and two stulls are placed under the cap, making the stulls and the end posts 3 feet apart. The next set alongside uses 12-foot timbers again, and so on. A single post of slightly larger size might be used instead of two and a slight saving made. The square set system is in use at only one of the mines.

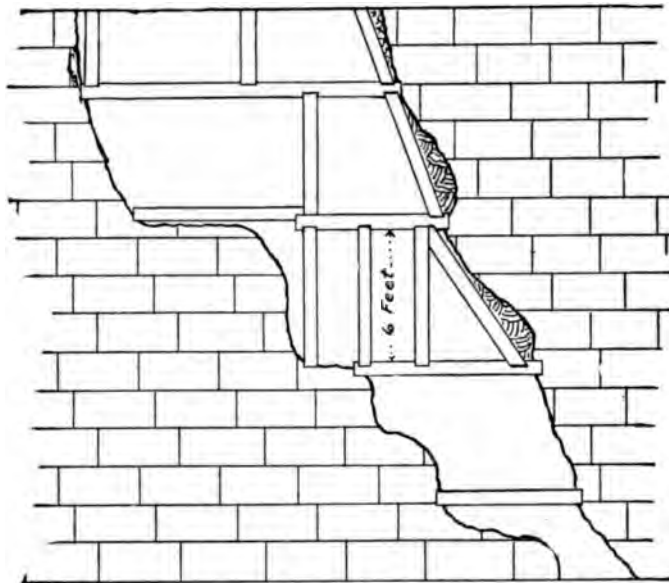
Overhand stoping cost in one case \$1.00 per ton. Contract stoping at \$2.25 per foot, 6 feet high and width of stope can be had in some sections.

In a stope at one mine one man with hammer drill breaks 4x4x6 feet or about 6 tons of fluorspar per ten-hour shift. The holes, about 8 in number, are placed irregularly though few are drilled at right angles with the face of the drift. He uses a stick of dynamite in each 4-foot hole shot. It takes about 40 minutes to put in 2 holes and shoot same and he tries to put in this number every 2 to 2½ hours. Sometimes it takes from 1 to 1½ hours to drill. One shoveler and trammer is used for each three or four drillers and he is said to be capable of sending out from 30 to 42 cars of about 1,800 lbs. each.

If the stopes are very narrow, 1 to 2 feet for example, one man using hammer drill will not break more than from 1 to 2 tons per shift.

In highly inclined veins with fairly solid walls, where in wide shoots, the caps on the foot wall side are hitched into spar or rock, while on the other side they rest on posts and may also be hitched; no timber or hangers are used lengthwise of the vein; the sets are set 4 feet center to center; timbers dapped 4 inches except posts; lagging is only used where

absolutely necessary. The accompanying sketch illustrates this method:



Ideal sketch of vertical cross-section of a portion of Memphis Vein showing method of timbering.

In narrow sections stulling only is done.

In one mine where large long stulls are necessary, 20 inches in diameter and 14 to 30 feet in length, it costs about \$10 to install one stull; the largest requiring a day's time and as high as 12 men. Such stulls are placed every 7 to 8 feet apart. Where posts are used to support them half and half daps are used. Nearly all the long stulls are hitched into the limestone walls. Such hitches are cut by moils, which are similar to a drill but have four sides drawn to a point, where the drill has two drawn to an edge; they make the hitches 5 to 6 inches deep at the bottom and 12x12 inches square. It takes two men to cut one hitch, one shift in limestone, while in calcite it requires only $\frac{3}{4}$ of a shift.

The drilling practice in the drifts of this mine consists of drilling three holes in a vertical row within one or two

feet of each wall, the holes being angled toward the wall. This creates a break on either side, after which the center may be readily broken down. In overhand stoping the practice is put in an upright vertical hole first, if the face is square then to incline the following holes more and more away from the face. Hand drills were used in most of this work, where hammer drills could be used to advantage.

In the wide stopes 4 men handling 2 air drills shoot down 50 tons per shift without timbering. One air drill and 2 men in an 8-foot stope shoot down about 10 tons per shift.

In drifting, 4 men using an air drill, working double shift, run 8 feet and timber in a week.

In this mine they shoot twice a day. The shots consist of from $\frac{1}{3}$ to 9 sticks of 1-inch 40 per cent. dynamite per hole, with depth varying from $1\frac{1}{2}$ to 6 feet.

At another mine they stull between walls with about 12-inch timbers, lagged at top of stope. Averaged 14 tons per day from wide stope, 4 drilling and shooting and 2 hustling, with a reported cost of 75 cents per ton of ore at mouth of shaft.

In timbering flat fluorspar deposits ordinary drift methods are employed for gangways. For other portions vertical stulls are largely used.

Open-Cutting.—This is indulged in to greater or less extent for gaining the secondary or altered deposits. Open cuts have been made to a depth of 45 to 60 feet for zinc carbonate, etc. Open cuts for gravel fluorspar have seldom been made deeper than 16 to 20 feet.

At the smaller cuts all the work is done by hand. At the larger ones surface debris is removed by scrapers, either ordinary or wheel scrapers being used, the latter being the most economical and expeditious.

Below this, picking and sometimes blasting is resorted to. The walls are usually stulled apart by timbers too light to serve the purpose. This fact, and the further fact that such openings become a receptacle for surface waters, makes frequent cave-ins possible, hence somewhat hazardous to operate, though against this is considered the greatly reduced cost of getting out the mineral, and the advantage of recovering all the surface minerals. As the men are exposed, work

can only be done in good weather. Again, when the deeper work is done, the open cut is always a hindrance, and incurs extra expense.

Timbers 6 to 12 inches in diameter are used for stulls and simply wedged between the walls, sometimes a block is placed between the end and the wall for this purpose. Where the wall will not stand, lagging is used. Sometimes sets are put in, as in underground work.

In the gravel fluorspar cuts, little or no timbering is used and the fluorspar largely mined on contract. In one instance, the surface was stripped and crude lump fluorspar put on dump by miners at \$1.25 per ton. For gravel, the company furnishing a washer, 75 to 85 cents per ton is paid; for cleaned lump, from \$1.35 for No. 2, to \$2.25 for No. 1 is paid, on dumps at mine.

In contract open cut work, where a small hoist and incline were used, 75 buckets of 300 lbs. each were raised per 10 hours. The cost of mining, two men in cut, one engineer dumper, was 60 cents per ton, and 40 cents per ton additional for washing spar; as \$1.50 was received per ton, 50 cents were cleared by the contractor.

Ventilation.—The ventilation is ordinarily good, as the shafts are shallow and the drifts short. In cases where the air is poor, most commonly resort is had simply to stove piping, a fire being either built in a pan beneath or a small wood stove installed. As the pipe is long, a good draft is induced and a shaft may be cleared in a few minutes of dynamite smoke or carbonic acid gas. Small fans or blowers are used at times, attached to the hoist or the engine that runs the log washer, while where compressed air is used a small blower fixes the air nicely, or no blower at all is used;* again, small blacksmith bellows are operated by hand and are satisfactory for small shafts.

Lighting.—The mines are lighted with either oil or candles, largely using oil lamps. It is considerably costlier to light with candles; the cost per day per man is about 5 cents. One of the mines was lighted with electric lights.

*Air from a compressor is, as a rule, too impure, from the partially burnt lubricating oil, to serve for "good" ventilation.—C. J. N.

Machinery.—But few of the mines are equipped with machinery. Besides the hoists, which have already been mentioned, boilers, both horizontal and vertical, are in use, varying from 8 to 200 horse-power.

Pumps, a necessary feature of the equipment, after water level is reached, are small, all the smaller shafts being readily unwatered by pumps of 2½-inch suction and 2-inch discharge. The most water made by any mine in the district can be handled by a pump of 7 inches discharge, and only three or four mines in the district have necessitated approaches to this size or a discharge of 500 gallons per minute; the most requiring a 4-inch discharge or less than 75 gallons per minute. Pumps of various types are in use, though in sinking the single-acting seems most satisfactory. Hand pumps are used to some extent, but they give a great deal of trouble. A few plants are equipped with air compressors, for from 2 to 8 drills. Both steam and gasoline engines of various types are in use, the latter being used more in prospecting or preliminary work, the steam engines more at a later stage.

Hoisting.—In prospecting work, the common windlass is much used to depths of 100 feet, though it is not economical to use it for depths exceeding 75 feet.

The accompanying photograph illustrates the common horse whim which is largely used. Such a whim may be easily and cheaply constructed, costing only about \$25.00. The two outer uprights, with two inclined braces, are about 14 feet high, and support a beam about 24 feet in length bolted to them. At the center of this is a pivotal-mortise in which the tenon on the central upright which supports the drum fits. A hub is made with four spokes, near the end of which 4 quarter-segments are fitted. Two hubs are used, one for top, the other for base of drum; the drum is attached rigidly to the upright. The drum may be made 3 feet in length, of 2x4 inches pieces nailed 2 inches apart to the segments. It is braced by pieces extending from the basal spokes to the upright. About 18 inches above the height of an ordinary horse a horizontal bar, from the end of which the inverted Y-shaped saddle irons are suspended, is mortised into the central upright. This bar is 9 to 10 feet in length. The horse gear is attached to the saddle irons. The rope, 1½

to $1\frac{1}{2}$ inches manila or $\frac{5}{8}$ to $\frac{7}{8}$ inches steel cable, is wound around this with both ends loose having about three rounds on the drum when two buckets are used, or it is fastened to the drum when only one is used. These do not have breaks and the horse or mule, usually blind, is entirely depended on. The steel whim is used to some extent. The man operating the whim is usually used also to drum buckets. The steel horse whim, while strong and having the advantage of a brake, costs about four times as much the ordinary wooden construction. It is serviceable in prospect work to depths of 200 feet.

One of the prime advantages of engine hoists over whims lies in the greater number of buckets that may be raised per day by means of the hoist. Where such hoists have been put in, the 8-h. p. is most commonly used, less frequently 12 and 25 horse-power, while only three or four 35 or 50 horse-power are in use in the district. Only about three-fourths of the hoists in use are of the geared type, and the friction type is rapidly being replaced by geared hoists.

Derricks of various sorts are in use, most of them quite crude. These are usually made simple, with the hoist in an engine room separate from the derrick. The Joplin type derrick could be used in a great many instances, with the saving of one man; this type is in use in only two or three instances here. By its use, only one man is needed to fire boiler, run hoisting engine and dump tubs. The ordinary derrick has simply to be modified so as to be able to support the hoist at the height above the ground that the trackways for ore and waste dumps are to be, and the boiler in a shed adjacent, so that a minimum of running would be required. The writer has used this type to good advantage.

Derricks from 18 to 50 feet in height are in use. About a 30-foot derrick serves most purposes. The higher ones are used in connection with milling plants. The lower ones are used where a whim is used or where the shaft is well situated for a dump. The timbers used are seldom over 8x10, though some good derricks with large timbers, 12x12 inches, etc., have been put in. Most derricks are vertical posts and those of both vertical and inclined are in use, though the latter is

preferable. Tripods have been used in only two or three instances.

Buckets are almost exclusively used in hoisting. Skips are used in one or two slopes. The Rosiclair mines can boast of the only cages in the Kentucky-Illinois district.

Labor and Miscellaneous Cost Data.—The miners employed are for the most part farm hands who have had little or no experience in sinking, blasting, etc. Wages paid foreman are \$1.50 to \$3.50 per day of ten hours. Drillmen get from \$1.50 to \$2.50. Helpers from \$1.25 to \$1.50. Hustlers get from \$1.00 to \$1.25. Head of shift \$1.50 to \$2.50. Surface workers get from 50 cents for boys to \$1.25 for men, according to work done. Dumpers usually get \$1.25. Hoisterman \$1.50. Engineers and pumpmen \$1.50 to \$2.00. A whimman with a mule gets \$1.50 per day.

The shifts vary from 8 to 12 hours in length, being rarely of other lengths than ten hours, and the wages named are for that length of time. Eight-hour shifts are in use only where it is necessary to have the crew constantly at work owing to excessive water. One or two of the companies use a 9-hour shift, paying the same wages as in the 10-hour shift. Very rarely, 12-hour shifts are had, except that many engineers and pumpmen are required on duty 12 hours.

The number of men employed in the mining division varies from 3 to 20 per shift, according to the methods employed and extent of work carried on.

The cost of mining the gravel spar, putting it on the dump, where as many as 50 tons are hoisted per ten hours, is 32½ to 34½ cents, exclusive of cost of timber, which is about 27 cents; making the dump product, allowing for 15 per cent. waste that is taken off in washing, stand at 59½ to 61 cents per ton. This is less than the cost of mining coal in Western Kentucky. Contracts for smaller tonnages are taken for putting on bucket only at 75 cents, while as much as \$1.00 to \$1.25 per ton has been paid for open cut gravel deposits, and \$1.50 for hacked lump. The cost of lump could be materially reduced with large tonnages and at a number of the mines does not exceed \$1.00 per ton. These costs are exclusive of costs of dead work necessary in driving through pinches, first cost of sinking shaft, etc., which add materially to these costs, sometimes more than doubling them.

The force necessary of the kind of workers employed, with the method here described for raising 65 to 75 tons of mine run, is: 1 foreman \$50.00 per month; 8 miners at \$1.25 per ten hours; 3 surface men at \$1.00 per ten hours; 1 engineer at \$1.50 per ten hours. This crew could be reduced by at least two of the surface men, with the proper dumping facilities. Below 150 feet at one mine, at wide stopes, the spar is put at mouth of shaft for 75 cents per ton.

Miners contract to take out No. 2 lump spar and hack it clean from open cut or shallow shaft for \$1.35 per ton; the gravel, including washing, at 85 cents. At one mine they got for lump and gravel unassorted \$1.25 per ton. As high as \$2.25 per ton has been paid for open cut hacked lump of better grade, on the dump ready for the haulers.

One large company reports the average cost of all grades of fluorspar at \$5.00 per ton f. o. b. cars at shipping point, while another places it at \$6.00. The average costs in Kentucky and Illinois are about the same.

Contract work has not proven very satisfactory in the district as a whole. The first cost is materially less in many instances when paid for on contract, but this cost is in most instances more than made up by the necessary amount of doing over what they did poorly. The writer has in a few instances gotten some first-class work from the contractors by having strict written contracts providing for supervision and forfeits, but it is difficult to get many contracts of this kind. One of the large companies that formerly did a large part of their work by contract, has nearly all its work done now by day labor, and the president of the company tells me he finds it cheaper, if anything, than the old way.

At the small mines, boilers consume from $\frac{1}{2}$ to 2 cords of cord wood per ten hours, while the large ones consume 35 to 50 bushels of coal per day. For coal consumption at mines having mills in connection, see detailed mill descriptions in another chapter.

Mixed oak lumber for timbering costs \$1.25 to \$1.35, and all white oak a maximum of \$1.75 per 100 feet, against \$3.00 per 100 feet for pine in the West. The cost of round bark-bearing timber, 4 to 5 inches in diameter, is one cent per lineal foot; for 6 to 8-inch, $2\frac{1}{2}$ cents per foot are paid. For 12 to

14 inches timbers 12 to 14 feet long, in one locality, the price paid is 20 cents per stick. For split lagging 5 to 6 feet long \$1.00 to \$1.25 per hundred feet is paid. Such lagging is often used in prospect shafts.

Cost of Hauling.—This varies somewhat, depending on character of road, the wagoners in many instances maintaining the roads themselves:

1 to 1½ miles	25 to 35 cents per ton.
2 to 2½ miles	40 to 55 cents per ton.
2½ to 2¾ miles	60 cents per ton.
2¾ to 3 miles	60 to 75 cents per ton.
4 to 4½ miles	90 cents per ton.
5 to 6 miles	\$1.00 to \$1.25 per ton.
8 to 9 miles	\$1.35 to \$1.50 per ton.
12 to 14 miles	\$1.50 to \$2.00 per ton.
16 to 20 miles	\$2.00 to \$2.50 per ton.

The lower prices obtain where the haulers can bring coal or other supplies to the mine, and hence get paid for both going and return trip.

Transportation.—At present there are but two lines passing through the Western Kentucky District, both belonging to the Illinois Central Railroad; hence, the absence of competition and the high freight tariffs. The Illinois Central also controls the Golconda-Reevesville branch which handles the larger part of the railroad fluorspar shipments of Southern Illinois. A small amount is shipped by the Louisville and Nashville Railroad at Shawneetown, Ill. A part of the Kentucky product is transported in barges by way of the Cumberland River to the Ohio, and put on the railroad at Joppa or Brookport for northern points. When the river is very low, some of the Illinois shipments are necessarily barged on the Ohio at Brookport, instead of to Golconda. Illinois mines also make use of the Ohio River, eastward to Evansville, while Kentucky shippers do not. The Tennessee river borders the Kentucky district on the west, but is of no service at present, being too far from any of the producing mines. Shipments from northern Livingston and Crittenden could readily be

made by way of Golconda. Owing to the use of an incline, as at Golconda and Brookport, cars can be loaded on barges. At present, Illinois shippers have an advantage in railroad freight rates of \$1.00 per ton over Kentucky shippers.

The rivers are open to large boats only a part of the year, making such transportation unsatisfactory, especially on the Cumberland.

A number of surveys have been executed with a view of putting belt lines to the mines in Western Kentucky, but as yet nothing has been done more than make the surveys. It was reported recently that the Louisville & Nashville intended building a line in the district. If this were done, it would help the district wonderfully, since the rates would be reduced so that Kentucky could compete with Illinois, with the result that the bulk of shipments would inure to Kentucky. It can be said without qualification that Kentucky can supply the product to meet any demand, if given proper transportation facilities.

CHAPTER V.

MILLING METHODS.

In the preparation of fluorspar for the market, three processes may be involved, washing, crushing and separating from other minerals and rocks, and grinding; sometimes the first process only; again, the first and second; while a small part undergoes all three of the processes.

Washing.

Log and gravity washers are chiefly in use in Kentucky, while Illinois mills make use of cylindrical washers, washing trommels and automatically-sprayed shaking screens. In some of the mills the rougher jig serves merely as a washer; a practice inexplicable when the cost between a serviceable washer and a 5 or 6-cell jig is compared.

Log Washers.—The log washer, consisting usually of an octagonal log to which iron blades are attached, is now commonly used. It is from 12 to 18 feet in length and 12 inches in diameter. The blades in most cases are set so that one blade is one inch beyond the preceding one. Where the fluorspar is mixed with a great deal of clay and is quite dirty, they are set the width of a blade or four inches beyond the one preceding, thereby permitting slower movement. When still slower movement is desired, either the number of revolutions is reduced, which is preferable, or every other blade is left off. The logs are inclined usually from 1 to 3 degrees, the latter being the most satisfactory, and are run commonly from 12 to 14 revolutions per minute, and again as high as from 25 to 40. The troughs in which the washers are set are 2 feet deep and of like width. Single logs are used at some of the mines; others have two sets side by side; while still others have them placed tandem; for uncommonly dirty

fluorspar a 2-inch stream of water is applied to the overflow end, while at the lower end a man is stationed to shovel the product in. A single washer requires $1\frac{1}{2}$ horse power to operate it. The cost of washing averages 25 cents per ton. When properly manipulated, the log washer is more efficient and cheaper than the gravity washer.

At the Memphis, Mr. Nunn has arranged an automatic feed for the washer. There is a trough inclined 40 degrees, with a heavy door closing it at the bottom. Into this the skips drop the ore. An iron rod is attached to the washer, and at each revolution admits a small amount of vein stuff by automatically raising the door. At 14 revolutions per minute, the 16-foot washer here handles about 20 tons per 10 hours.

Gravity Washer.—The gravity washer consists of an inclined trough about one foot wide, the sides flanging toward the top. These troughs are 8 to 10 inches deep, and constructed of inch planks, usually of oak. At times the bottom and sides are lined with sheet iron. Such troughs are from 25 to 75 feet in length. At the upper end the trough is deepened and widened so as to form a bin into which the spar may be dumped, having a capacity of 50 to 100 tons. The bin and trough are inclined 10 to 12 degrees, the former less than the latter. The whole is elevated a sufficient height to give room for settling boxes. The height is gained by the ore, either by arranging the washer so that the ore may be dumped into it from the shaft-tub, as at the old Memphis washers, by belt and cup elevators as formerly at the Columbia mine, or by taking advantage of a steep slope. The height at the lower end is usually about 6 feet. Those having two at the end, have them placed at the foot of the washer. A steady $1\frac{1}{2}$ to 2-inch stream of water, sometimes two, is sprayed with hose upon the fluorspar in the bin; sometimes by boys employed for this purpose, and again simply from a pipe. A walk-way is provided on each side, on which a boy or man may walk to loosen with a hoe or rod any clogged fluorspar. The washer at the Tabb mines is a typical washer of this type. A modification of this is seen at the John mine for its semi-clean fluorspar; simply a short 10-foot

trough is used with a two-inch stream of water playing on it.

The gravity washer is but little used now in the district. The cost of washing by it is 25 to 35 cents per ton, which higher price some claim is compensated by its cleaning better the very dirty fluorspar. This, in comparison with work done by the log washer, appears not to be the case, the log doing equally good or better work; the losses are also greater with gravity than with log washers. In fact, a great deal depends on the manner in which either is handled.

Other Washers.—At both Fairview and Rosiclare, where the spar is semi-clean, shaking screens with automatic sprays are utilized. These sprays are made by arranging a row of holes, three or four inches apart, in half-inch or one-inch pipes, set parallel six inches apart, so as to cover surface of screen at an elevation of about 18 inches above the screen. In both these mills there as previously used, in addition, and to which the spar was first admitted, a cylindrical iron washer, with a spiral of sheet iron 6 inches wide lining the cylinder. Such washers were about 12 feet in length. While they wash the spar very well, they are superfluous, both it and a shaking screen washer are employed for semi-clean spar, either alone being sufficient, perhaps equally efficient, though the shaking screen requires less space, being only 6 to 7 feet long.

At the Lead Hill mills, as also at the Mary mill, washing trommels are employed, of round perforated metal, with cups attached. These are 6 feet in length. These are quite efficient for the character of fluorspar they handle, which is not very dirty.

Summing up, the log washer appears preferable for dirty vein stuff, while the sprayed shaking screen or washing trommel is preferable for the cleaner product.

Screens.—Most of the washers have only one screen at the end, though in some cases two are used for two sizes. In the case of gravity washers where two are placed at the end, they are stationed at the end of each trough, two troughs branching off from the main trough, while on the sides of the latter one or more screens may also be placed to gain ca-

capacity. The screens vary, $\frac{1}{2}$, $\frac{5}{8}$ and 1 inch being most commonly used. Grizzlies are also used for this purpose, made from iron bars, inverted rails, or inch wood strips. Screens or grizzlies are commonly not over 4 feet in length and inclined 30 to 40 degrees.

The screens placed at the base of the washers are ordinarily of the stationary type, while at some of the mills a shaking screen is employed. The washing trommel acts partly as a screen itself. The undersize from these form one size and the oversize another, where two sizes only are made in the case of gravel flourspar. The Empire mill makes three sizes,—fine, medium and large; the latter above 1 inch. This is the only mill where the product is crushed simply for the purpose of sizing. Most of the gravel spar is then ready to be hauled to storage dumps or bins, to await shipment. In other cases, it is first hand-picked, sometimes in the bin at the base of the washer screen, as at the Memphis mine, or again on a plank table built just under it, as at the Pogue and Rosiclare, or an iron sheathed wooden picking belt, as is used at the Lead Hill mills; or a white rubber belt conveyor, as at Fairview. At the Kentucky mill, the man shoveling into the crusher serves as picker. Usually from two to four men are employed. The treatment for gravel and lump products is somewhat similar. The lead and No. 1 lump are picked out to go to separate bins; the gangue as calcite; limestone and barite are also picked out if least abundant, and the No. 2 flourspar or that to be milled, goes over at the end of the belt. The last two products change places according as one or the other is most abundant. In some cases the lumps containing zinc sulphides or carbonate are picked out and dropped into separate chutes.

The treatment described is all that is necessary for preparing natural gravel for market, or No. 1 lump for grinding, if none or insufficient other minerals are intergrown to require more elaborate treatment. If more elaborate treatment is required, the foregoing always precedes as preliminary treatment.

We will now consider in some detail, the more elaborate practice, taking up first the various ore dressing problems, in

which fluorspar is concerned, and describe plants used, and finally we will treat of the fluorspar grinding sections accessory to a few of the plants.

Ore Dressing Problems.

Five distinct problems are offered in the concentration of ores and spars in which combinations of two or more of the following are to be dealt with: Lead (largely galena, having a specific gravity of 7.5); zinc (sphalerite, sp. gr. 4.01, and smithsonite, sp. gr. 4.38); fluorite, sp. gr. 3.13; barite, sp. gr. 4.45; calcite (including limestone), sp. gr. 2.72; and quartz (including quartzite and jasperoid), sp. gr. 2.65. The problems are as follows:

(1) The saving of lead, zinc and fluorite, with any or all of the remainder as tails.

(2) The saving of lead and zinc, with any or all the remainder as tails.

(3) The saving of lead and raising the fluorspar to a No. 1, with calcite and any or all of the remainder as tails.

(4) The saving of fluorite and barite, with calcite and any or all of the remainder as tails.

(5) One rarely presenting itself in this district, but much involved in Central Kentucky ores, is the separation of zinc and barite, with any or all of the remainder as tails.

The difficulties of mechanical separation, and requirements necessary to overcome them, presented by the problems are here outlined:

1. The nearly equal specific gravity of what is to be secured as concentrates and tails, presented by all the minerals involved, exclusive of the lead, which has a difference of gravity sufficient to separate readily from the others by the ordinary methods of concentration.

To overcome this, a practically perfect sizing system, in order to prevent grains of the minerals of unequal sizes to be in juxtaposition to each other on jigs or tables, is necessary.

2. The first, third and fourth present the unique phase of requiring a saving as concentrates of 75 per cent. or more of the product put through the mill; whereas, the usual percentage of such product varies from 3 to 20 per cent., 15 to 20

per cent. being rarely obtained. The percentage of tails in the second more nearly approach the ordinary.

This will require an increase of capacity at the tail end of the mill, and a relative decrease at the head end, which permits the tailings elevator to be done away with.

3. The fine granular condition of most of the products of the first, especially, while a portion of the deposits of the other four types present the same difficulty, resulting in the chattering of particles of the different minerals, unless the ore is very finely crushed. In this case, finer crushing, largely to below 3 millimeters, for the finer grained products. The finer crushing necessitates the use of cleaner jigs from the start, nothing being gained by use of roughers, as in the Joplin district, is requisite.

4. (a) The unequal hardness of the minerals involved, especially quartz, as against others, resulting in fine comminuting of the ore minerals (upon fine crushing, made necessary by the third condition,) the percentage of fines below 1-200 inch becomes large; hence the loss of mineral as dust in the dry processes, and the sliming of it in the wet. Here we must resort to the use of rolls and crusher that will permit of the least comminution of fines.

(b) This involves the further factor of cohesion of fine particles for each other, presenting two difficulties,—the difficulty of readily sizing the particles of the aggregate formed, the ready clogging of the screens on the same account. The sizing of products below 1-200 inch is not practical; hence, separation of these is almost impossible and the losses from this source have been considered equal in consequence with that of reducing the fluorite content of the sphalerite.

This necessitates: (1) The use of very fine mesh screens. (2) Such motion and action as will prevent clogging, as in the Cohenour-Ratcliffe screen.

5. The cleavage forms of minerals, the fluorspar breaking into minute, imperfect tetrahedra and octahedra, the calcite into rhombohedra, the others breaking down more readily than these, and the fluorspar more readily than the calcite. The manner of crystallization and facility of cleavage alone directly affects this, the hardness being only indirectly concerned. The various sizes so adjust themselves as to balance

larger particles of fluorite with smaller ones of sphalerite or barite, and larger ones of calcite with either of these three.

This is quite difficult to overcome and is affected to slight extent by the type of crusher and rolls used. Finer crushing perhaps reduces the force of this factor slightly.

6. The first presents the further difficulty of the necessity of making four separate products, where three are necessary only ordinarily, as in the next three. Since the fluorite is nearer in specific gravity than either of the other two, the attempt has been made to have it go over as far as possible with the tails, disregarding the loss thereby entailed.

This may be partially overcome by drawing off the mixed fluorite and zinc, and handling the mixed product on separate tables and spitzlutzen, etc. The saving of the fluorspar even as a fluxing spar, will add largely to the profits.

Special Separation Methods.

Fluorspar and zinc sulphides are now separable by at least two methods: First, Sanders' flotation process; second, Electrostatic separators. For descriptions of these see chapter I.

A third method has been suggested as possibly capable of effecting the separation. Taking advantage of the difference in decrepitating properties of the minerals upon heating, as has been done with barite and sphalerite. One of the difficulties in the presence of fluorspar with zinc in the reduction of the latter, may now be readily overcome through the making of acid-proof or basic retorts on an economical basis, as is done in the Queneau composite retorts. However, fluorspar is also objectionable in the roasting of zinc, preparatory to its reduction in the retorts, since it forms hydrofluoric acid, which attacks the lead-lined sulphuric acid chambers at 1,000 degrees Centigrade. Concentrates should run 2 per cent. less of fluorspar.

Crushing and Concentrating.

Breaking Floor, Receiving Hopper.—The methods by which the ore reaches the mill have already been described; hence, we will begin at the breaking floor above the

ore bin or hopper. This is usually a few feet lower than the hoisting floor or height from which the bucket or skip is dumped. A grizzly of round iron bars, set 4 to 6 inches apart, is usually provided. All that goes through passes directly into the hopper; that remaining, is broken and partly picked by hand. In instances where the picking table precedes the hopper, the picking is done first, while in other cases the picking is done just before the ore enters the crusher. It is washed previous to the picking in cases where it receives washing. The hoppers are variously constructed, but most of them are on the self-feed basis, being elevated sufficiently to permit the ore to feed by gravity, the bin being "V" shaped with the front limb vertical, the back one inclined, while some are made still more efficient by inclining also the two sides, within a few feet of the bottom, toward the center, making sort of an inverted pyramid. The main inclined surface dips 40 to 45 degrees, while the smaller inclined parts dip much less, 25 degrees or so. These are constructed to have a capacity of 100 to 300 tons. Most of these have simply wooden drop doors, automatic gates only being in use at Fairview. From these the ore passes into a launder, sometimes having a stationary $\frac{3}{4}$ -inch perforated screen in its bottom, that the fines may be separated, the oversize going to crusher, the undersize, either direct or by elevator, to rolls.

Crushing Machinery.—For crushing the ore jaw breakers are commonly used, though a gyratory crusher is employed at Rosiclare, and a Williams at the Pierce. At two of the mills, the Evening Star and Evansville, two crushers are employed, one after another. For finer crushing, from one to four sets of rolls are employed, the last as chat rolls whose products go to sand jigs or tables.

Elevating Machinery.—Belt and chain elevators with cups, are commonly in use, while, for dried products, as in the Evening Star mill, or in the grinding sections, helicoid conveyors are used.

Sizing Machinery.—Some of the mills have complete trommel-sizing systems, as the Robinson and Cave-in-Rock mills, while others, as the Kentucky for example, have little or none.

Revolving trommels of perforated metal are the preponderant type; shaking screens are used in conjunction in some instances, while the Ratcliffe-Cohenour screen is used at the Nancy Hanks. Dry sizing is only employed at the Evening Star. Wire and perforated metal screens are both employed, the latter usually with round perforations.

Jigs.—The screens deliver the products to the jigs sometimes by launder direct onto the beds, and again first into a barrel or spitskasten, permitting the surplus water to overflow, and the partially de-watered product to go to the jigs. De-watering is advantageous, since it prevents too much water running over the beds.

Most of the mills have Hartz jigs, either of the Cooley or Faust pattern. The Lead Hill mills have the New Century jigs, while at Rosiclare a Hancock jig has recently been installed. At the Nine Acres mill, the Big Four (adjoining LaRue mine,) and the Lucile have used hand jigs; but only at the first did they show results, and at none were the results satisfactory. The complex condition of the ores make their practical use in this district out of question.

Jigs equipped with Hartz or New Century eccentrics are made with from three to seven cells. Three-cell jigs are in use at the Robinson and Pierce mills. At the former, for concentrating lead and fluorspar; at the latter for separating red clay and silica from the fluorspar, which it does fairly well.

From my experience in milling in the district, as well as from investigation at the various plants, I find no gain in using jigs with more than four cells, while those of less number are undesirable.

Settling Tanks, Classifiers, Spitzkasten.—Settling tanks are used in many of the mills, at the end of the rougher and cleaner jigs, to settle the overflow product. Hydraulic classifiers are used somewhat in connection with the tables. A simple form being an inverted pyramidal box containing another on the inside, with its sides about 3 inches from the outer one; the inner one being open at the bottom so as to permit free passage of the water and ore between the interior and exterior; the outer box having an overflow launder, and

a spigot near the base for letting the product out upon the first bed of the jig.

A spitzkasten is employed for dewatering ore, etc., in one instance. Settling troughs are also employed in connection with settling ponds, to catch slimed products, that they may be re-run on table in some instances; in others, simply to prevent ponds from being filled up. Even when these are used the ponds frequently require cleaning out.

Spitzkastens, hydraulic classifiers, etc., could be used in many of the mills to good advantage in sizing the finer products.

Tables.—Those in use in the district, are all of the side jerk type. The Riley, Mary and Fairview use Wilfley; the Lead Hill group, Ford tables, and practically all the remainder are Overstrom.

The Wilfley at Fairview does the best work of any of those the writer has seen in operation. The differences in products made by the various tables is small, though those with tapering riffles are best; the middlings from all going partly to waste. The success in the use of any of the several tables, depends largely on management.

Water Supply.—Water is supplied principally from artificial ponds, the same water being used over and over again. Centrifugal pumps are largely employed; more rarely duplex are used.

Power.—Power is supplied from engines of from 40 to 200 horse-power, while the boiler capacity varies from 80 to 400 horse-power. Boilers are of the horizontal return tubular type, excepting the Evening Star, which has vertical tubular boilers, and the Pierce, which has the old Lancashire type.

Capacity, etc.—One of the features especially characteristic of the mills of this district is the arrangement of launders between the several jigs, rolls and elevators so that products not sufficiently clean may be re-run. Undoubtedly, treatment of such products on separate jigs, etc., would yield better results.

The re-running of the products on the same jigs, etc., as well as the insufficient capacity of many of the mills, at the tail end, to handle the larger percentage of concentrates than is the case with ordinary mills, both tend to much reduce the capacity of the mills as compared with the capacity of mills of the Joplin or Wisconsin districts. The capacity of 100-ton mills is reduced to 20 to 30 tons.

Cost.—The average cost of milling is about 75 cents per ton should be able to approach the lower figure. A number of ton in the concentrating section; the cost varies from 50 cents to \$1.00. By economical management, most of the mills typical Kentucky-Illinois fluorspar mills are described in detail in this chapter.

Grinding.

The No. 1 hand-picked product, or in some cases the better mill fluorspar concentrates, are used for ground fluorspar, and are sent to the dryer in the grinding section.

Dryers.—Two types of dryers are in use, the direct fired, horizontal sheet dryer, and the horizontal steam dryer. For the latter, either live or exhausted steam is used, although live steam is most efficient. Since the iron sheets rust somewhat on contact with the steam from wet fluorspar, it would be better to use enameled plates. The Kentucky Mill dryer is being thus equipped.

Grinding Machinery.—Four styles of grinders are in use: (1) Buhr mill; (2) Williams pulverizer; (3) Tube mill; (4) Griffin mill.

Bolting.—Some of the mills bolt the product; others do not. Revolving bolters and impact screens are in use for this purpose, the mesh varying from 50 to 85.

Barreling and Sacking.—Most of the product is now barreled for shipment. Both vertical and horizontal cam settlers have been employed. The barrels cost from 25 to 30 cents each, and, owing to the increasing cost of barrel stock, it may become necessary to quit barreling, and sack the product instead. The barrels hold from 500 to 600 lbs. each. One of the mills sacks the product in 100 lb. heavy canvas

sacks. Besides a less first cost they have the additional value of being returnable at small cost to the mill. A small part of the ground product is shipped in bulk.

Bins, Elevators, etc.—Bins of usual type are employed. Both cup elevators and helicoid conveyors are in use. Common scales are employed for weighing.

Power.—That supplying the concentrating section also supplies the grinding section.

Men.—Two to three men are employed in grinding section in addition to those employed at picking table. One man looks after the grinders, and one or two are engaged at the dryer.

Cost.—The cost of grinding fluorspar per ton, exclusive of first cost of plant but inclusive of concentrating cost, is \$1.00 per ton. Kentucky-Illinois mills having grinding sections, are the Kentucky, Nancy Hanks, Fairview, Rosiclare and Pierce mills, all of which are described in detail in this chapter.

Kentucky Mills.

THE KENTUCKY MILL.

The Kentucky mill was erected in 1899, one-half mile southwest of the depot at Marion, to take the place of the Memphis mine mill of the Kentucky Fluorspar Company. As originally constructed, it was prepared to do grinding only. In 1902, a concentrating section was added in order to save the galena and to clean fluorspar of any gangue, such as calcite, limestone, etc.

The Kentucky Fluorspar Company uses ore both from their own mines and that purchased from local companies, though fluorspar used for grinding, comes practically all from the specially selected product of their Memphis mines.

The ore is received largely from wagons; sometimes from cars if it comes from the mines southwest of Crayneville or Mexico. After weighing on wagon scales, it is distributed to the various dumps, according to grade, upon the store yard; if suitable for No. 1 ground, it is dumped into the warehouse adjoining the mill.

The product is barrowed to an 8-inch, Blake type, crusher supplied with $\frac{3}{4}$ -inch stream of water; and, if containing much

calcite or other impurities, these are picked out before shoveling into crusher. The product goes direct to the first set of 10x14-inch rolls, where it undergoes further crushing. The crushed product is elevated to a revolving trommel of about 7-16-inch perforation, supplied with a $\frac{3}{4}$ -inch stream of water, and the undersize goes by launder branching into two launders, one of each feeding a cleaner jig of seven cells. The cells are 30x36 inches. The beds vary from 6 to 8 inches in thickness, most of them 7 inches. Perforated screens on the beds have, for first two cells $\frac{1}{8}$ -inch; next four $\frac{1}{16}$ and last $\frac{1}{32}$ -inch, perforations. The plunger cells are supplied with two 2-inch streams for the first, and one 2-inch each for the other six, though the streams are not always full size.

Lead concentrates are obtained from the first cell; middlings from the second, which go to elevator and to second set of 10x14-inch rolls, from which they are sent again through mill; the next three supply fluorspar concentrates, the best of which, and usually all of the bed product, is caught in buckets and barrowed to a receiving pit about 8x15x6 feet, from which it is shoveled into the dryer elevator. The second grade crushed is wheeled to dumps outside the mill. The product from the last bed goes to waste dump by launder; the hutch product to chat elevator.

The lead is all shovel sluiced, this reducing the fluorspar content $\frac{1}{2}$, the fluorspar content being from 5 to 10 per cent., and about a 75 per cent. lead product is obtained. The amount of lead saved, while small, adds largely to the profits, since it pays practically two-thirds of the milling cost. The fluorspar concentrates for grinding are nice and clean, barring an occasional lead and calcite chat, sometimes also shale or limestone fragments, all of which, however, are absent from crushed for extra No. 1 ground. Most of the calcite goes over to the last cell of the jigs. The tailings carry from 10 to 20 per cent fluorite; remainder largely calcite, limestone, etc. The dryer elevator feeds the product to a direct heat dryer with sheet iron top. A constantly moving rabble keeps the drying product moving; the dried product going over at the end, where it feeds an almost horizontal helicoid conveyor, which transports the product to a cup elevator, which raises it to an

elevated bin of 50 tons capacity. This bin feeds the Pyle buhr mills, of which there are two, automatically. These mills have a capacity jointly of 50 to 80 barrels, or from $12\frac{1}{2}$ to 20 tons per day, the output increasing with coarseness of product, decreasing in finer grinding. The ground product is not bolted, but the mills are so set as to average an 85-mesh product, except in case of special orders, when the product is ground still finer. The ground product is elevated to the ground bin, and from this the barrels are fed. There are three barrel settlers of the horizontal cam type. For small shipments the barrels are lined with paper; otherwise, not.

The barrels weigh from 500 to 550 lbs., and average 535. The barrels are made at a cooperage belonging to the mill, and cost about 30 cents each. Each barrel is weighed as soon as filled, and weight marked on cover, as well as on record sheets.

All grades of American ground are supplied by this mill.

The power is supplied by a 90 horse-power Corliss engine and two boilers, one 60 and one 80 horse-power.

Water is supplied mill from an artificial pond, by a 4-inch centrifugal pump, supplying 260 gallons per minute. The water, after passing through the mill, passes over a series of settling troughs and into a smaller pond; thence again into the large pond.

There are three men employed in the jig section, and two in the grinding section; and, in addition, they have an engineer and two yard men, the last three being colored men. The capacity of the jig section is about 30 tons per day. Product to be shipped, is barrowed and weighed on barrow scales, and put directly in car on siding at the mill.

NANCY HANKS MILL.

This mill, a photograph of which is shown, was visited about a week before it was ready to operate. Its capacity is 30 tons per 10 hours. In handling ore of the Joplin type, its capacity would be 100 tons per 10 hours. In this district, where the percentage of heads is several times that of tailings, there is little that can be rushed over the jigs at the tail end.

The ore problem is practically a simple concentration of fluorite and galena, there being but a minor amount of calcite and sphalerite in the ore as it goes to the mill, and were it not for the difficulty of ridding the fluorite of metal chats, the separation would be comparatively easy. The ore is hoisted from the mine or dump and dumped on (1) 35 feet above the surface.

1. Grizzly of round 2 inch bars, set 6 inches apart. All small enough to go through grizzly passes into (2), while that too large goes to (3).

2. Automatic hopper. Capacity about 100 tons; ore passing from it directly to (4).

3. Spalling floor, ore broken to 6-inch, and shoveled to (1).

4. Screen $\frac{1}{2}$ -inch holes; ore passing through by launder to elevator (7) oversize, (5). Here ore is hand picked. No. 1 to separate dump, and calcite thrown out; remainder permitted to pass to (5).

5. 8x14 crusher, Blake type, from this to (6).

6. No. 1 Cornish rolls, 14x24-inch, from here to (7).

7. No. 1 elevator, 14-inch buckets; ore raised by this to (8).

8. Sizing trommel, 6 ft.x36 inches. Holes 6 millimeters, or little less than $\frac{1}{4}$ inch (8 mesh). That fine enough to pass through by launder to (9); that too coarse, to (10).

9. Main elevator 14-inch bucket, from here to shaker screens. (11-15).

10. No. 2 rolls, 14x24-inch; from here by launder to (7); and then to (8) again.

- 11, 12, 13, 14, 15. Five Cohenour-Ratliffe shaking screens, perforated metal, sizing to 5, 4, 3, 2, $1\frac{1}{2}$ millimeters. Oversize from 11, 12, 13, 14, 15, to 16, 17, 18, 19, 20 respectively. Undersize from 15 to 20 at present, but to 21 when latter shall be installed.

The Ratcliffe-Cohenour screen consists of a plurality of rigidly connected inclined screens, arranged in a tier one above another, with a means for vibrating them in unison laterally. A rotary ratchet wheel, situated opposite each screen, arranged so the vibrations of screens actuate it, trips a hammer so the latter may strike each screen after a pre-determined number of vibrations.

At this mill, the screens are inclined 15 degrees, all in one direction, screenings being supplied by launder from elevator to the uppermost screen. The undersize passing through, falls into an iron sheet trough, inclined in reverse direction from the screen, permitting the product to drop at the back of the next screen below.

The advantages of this screen are two-fold. First, it requires but a small amount of room, where in the trommel systems a large amount is required, necessitating a considerable addition in height of mill.

The Ratcliffe-Cohenour screen for five sizes, requires a space of less than 8x8x8. In fine sizing, cleaning the meshes is one of the greatest difficulties to be overcome, and this the hammer feature accomplishes effectively. It produces, however, still another favorable effect, the tonnage handled being largely augmented by means of the scattering of the product. The size of each screen is also small, compared with other screens, for handling an equal tonnage, about 20x30 inches.

16-20. Five 4-sieve jigs, Cooley pattern; size of beds 24x36 on all except (16), which is 30x42. Screens 16, 20, 26, 28 and 30 mesh. These are fed with two 1½ to 2-inch streams in back, and just enough 1½ inches water in front to cover the ore. Jig sieves a fraction smaller than screen from which it comes. 1st cell on each for lead, and for middlings and chats; remainder for fluorspar in main. ¾-in. to ¾-in. stroke, and 140 revolutions of shaft. Jig beds average 5 in. depth. Last two largely calcite, especially the last. Get No. 2 spar from No. 2 hutch. All chats and middlings to (22). Ore by barrow to ore bins. Tailings by launder to waste dump. The jig handling the fines has a barrel placed at its head, to carry the ore and water on to bed. (To be installed.)

21. Wilfley table, ore to bins, tailings to waste dump.

22. Chat elevator, 8-inch cups. Middlings and chats from here to (23.)

23. Chat rolls, 14x18-inch. Reground and sent to (8) and back through mill again, as at first.

24. Centrifugal pump.

Main mill room is 24x70 feet, and 16 feet in height, to screen room, which extends about 10 feet higher, while the derrick at shaft is about 45 feet high. The 100 horse-power

boiler is used in connection with a 45 horse-power engine to supply power for mill. A triple compartment pond 5 to 8 feet deep, has been made. The divisions being arranged, two for settlings of fines, and the last for overflow. This is supplied with fresh water, when necessary, from the mine. The water is pumped by a 4-inch centrifugal pump from the pond to a 5x5 tank above the mill, from which the water is piped to the hopper, screens and jigs. Have a fluorspar warehouse, iron sheathed, at depot at Marion, 30x60 by 10 to 14 feet in height.

Lead concentrates from jigs are re-run on a separate jig (usually the No. 19) using the regular beds. Losses believed to be smaller than by other methods, since most of the lead is caught on the first cell of the jig, upon which it is re-run. These concentrates show less than 5 per cent. of calcite and fluorspar. The fluorspar concentrates used for No. 2 ground contain probably 4 to 6 per cent. calcite, limestone, etc., which is cleaner than the usual run of fluorspar concentrates.

UNION CENTRAL MILL.

Problem:—To separate galena from gangue consisting of fluorspar, limestone, calcite, etc.

Ore hoisted by 8 horse-power geared hoist, and dumped on (1.)

1. Grizzly of 2-inch bars. That passing through to (2); that over to (3.)

2. Self feed hopper, 45° angle, 100 tons capacity. By launder to (4.)

3. Breaking floor.

4. 9x14-inch Carterville crusher. By launder to (5).

5. First set Carterville rolls, 24 inches; By launder to (6).

6. First elevator, to (7), 16-inch cups; 19 ft. high.

7. Trommel $\frac{1}{2}$ -inch perforated metal; that passing through screen to (8); that passing over, to (9).

8. Stevens patent jig, five cells; cells 30x42 inches; $\frac{3}{8}$ inch grates. Nothing is to be drawn off beds, except perhaps a little galena of first. There appears to be no gain made in the use of the jig, as it merely sizes the product to 3-16-inch and above, and this could be accomplished as readily by use of another trommel, except for the little tails going off end.

Chats off beds, by launders to (10); smitten or hutch product to (11).

9. Second rolls, 24-inch. By launder to (6) and back to (7).

10. Chat elevator, 6-inch cups; 19 ft. high. By launder to (12).

11. Smitten elevator, 14-inch cups, 19 ft. high; by launder to (13).

12. Chat rolls, 18-inch. By launder to (6).

13. Settling tank, very similar to spitzkasten. Consists of a double inverted truncated square pyramid; ore drawn off at side, at bottom going unwatered to first bed of 14. This is an advantage, as usually too much water is had on the beds. This measures 30 inches square inner, and 47 inches square outer; 38 inches deep. Water overflows to launder, going out of mill.

14. Cleaner jig, similar to rougher; six cells, 28x36-inch cells; screens on first $\frac{1}{4}$ -inch; on next floor, 3-16 inch; on last, 1-8 inch. Lead off first bed and hutch; other products from beds and hutches of 3d, 4th and 5th cells, with chats from 2d going back for recrushing to chat rolls. Tailings off 6th sell to (15).

15. Tailings elevator, 16-inch cups, 36 feet high. Tailings to tailings dump.

Mill supplied with water from spring, by 4-inch centrifugal pump. Power supplied by two 100-horse-power horizontal return tubular boilers, and 12 x 20 steam engine, 75-horse-power.

Building.—Main room 24 x 50 feet, and 16 feet high. Derrick 45 feet high with hoist at 38, and breaking floor at 35 feet. Derrick 14 x 14 feet. Shaft 6 x 9, cribbed with hewn timbers about 6 x 8 inches.

THE COLUMBIA MILL.

This is the only wet mill which has attempted the separation of lead and zinc primarily for their saving, and with the percentage of fluorspar too small to save as a by-product. Here a mill of the Joplin type is in service, with rougher cleaner and sand-jigs. Only two trommels are in use for sizing. Very little, and most of the time no, clean products are secured from rougher; if any, from beds only. The prod-

uct is sent on to the cleaner, and then to the sand jigs. Cleaned lead concentrates which, after shovel sluicing, still contain a percentage of zinc, are secured from the first cell and hutch of cleaner. The third fourth and fifth give off after sluicing a product consisting largely of zinc sulphide, associated with possibly 15 per cent. carbonate, and a small per cent. of fluorspar. The sand jigs give the cleanest zinc sulphide product, containing but little galena off first hutch. One of the points to be mentioned is that the jigs are so connected by launders that any portion of the jig products may be sent back over again. Two Overstrom tables are used for concentrating slimes, and the end hutch product of the sand jigs. Only fair results have been obtained by their use, as the fluorspar content, after running over them, is rather high. These tables are both used as cleaners, though if they were used as rougher and cleaner, a cleaner product would result, though their capacity would be less. The zinc concentrates average about 57 per cent. zinc. The low percentage results partly because of the amount of carbonate obtained.

EVENING STAR MILL.

The problem is to save the galena and sphalerite, and to tail the fluorspar, limestone, jasperoid, calcite, etc.

The large ore body at this mine, with its high lead and zinc values, makes the ore of peculiar interest; furthermore, it constitutes a type which, if properly concentrated, would make the county and district an important factor in the zinc market.

The ore is distinctly a metasomatic replacement of a limestone sheet, probably sheared, from the Ste. Genevieve limestone wall by the faulting. The extensive brecciation spoken of by Dr. Smith, was not recognized by the writer, in the ore. Fluorite varying from purple to brown black in color, constitutes 50 to 60 per cent. of the ore. The color appears to become darker as the percentage of contained jasperoid and sphalerite increases. The fluorite is granular, and from three to four times the size of the sphalerite grains.

Jasperoid, the next largest, constitutes, makes up 20 to 30 per cent of the ore; it is intimately intergrown with the fluorite.

ILLUSTRATION.

The sphalerite varies from microscopic grains to those $1\frac{1}{2}$ millimeters in diameter, disseminated in the fluorite, but to a somewhat greater extent in the jasperoid. The amount of sphalerite varies from 2 to 30 per cent. or even more, and the ore will average 10 per cent. Large crystalline sphalerite has been noted, but is rare. A small amount of leaching out of sphalerite and some residual calcium sulphide is found. The galena occurs usually as slightly distorted cubes from 3 to 5 millimeters across; 10 per cent. is common in some of the ore, but 5 per cent. is near the average.

A notable feature is that the galenite content increases with a decrease of sphalerite in the ore. A reason for this may be that galenite crystallizes more readily in fluorite than in jasperoid.

A small amount of partially altered limestone goes to make up the remainder of the ore. The calcite is found in less quantity than usual in ores of the district, there being probably not more than 3 to 5 per cent. of the ore.

Pyrite was only noted by the writer in one hand specimen, there being about 0.5 per cent.

Capacity of mill has not yet been determined. The ore is hoisted from the new shaft, emptied into cars and conveyed to dumps, where, for the present, it is being hand-washed and picked, by wheelbarrow dumped on platform by side of (1.)

1. No. 1 crusher, jaws set from 1 to 2 inches, passing by gravity to (2) in basement below it.

2. No. 2 crusher, jaws set at $\frac{1}{4}$ to (3.)

3. Bucket elevator No. 1 to (4.)

4. Slightly conical revolving dryer, the smoke passing through the dryer from its furnace and out through stack connecting with main boiler stack, the ore coming in at the end farthest away. The dried ore passes to (5.)

5. Helicoid conveyor. From this to (6) by (5 $\frac{1}{2}$.)

5 $\frac{1}{2}$. Elevator.

6. $\frac{1}{4}$ -inch screen; oversize to (2); undersize to $\frac{1}{8}$ -inch; $\frac{1}{8}$ -inch, $\frac{1}{16}$ -inch, $\frac{1}{32}$ -inch oversize of each to one of (7); undersize to next smaller, except undersize of last, which

goes to (9). The intention of this sizing is to prevent re-crushing of anything of under $1/32$ -inch.

7. Four sets of rolls. From these by (8) and ($5\frac{1}{2}$) again to (6.)

8. Right and left-handed conveyor placed below (7.)

9. Helicoid conveyors. By these to (10.)

10. Bucket elevators. By this to (11.)

11. Six brass revolving trommels, sizing from $1/32$ -inch to $1/200$ -inch, each trommel feeding one of (12), and over-size of 1st also going to separate bin of (12).

12. Seven bins, arranged to feed 2 of (13.)

13. Twelve Hooper Pneumatic tables, ore to (14). Tails to (15). Finest sized product over tables $1/170$ to $1/212$ -inch. Coarsest $1/32$ inch. That, under $1/212$ is also sent to table, but separation is unsatisfactory.

14. Ore bins.

15. Tailings.

Power consists of a battery of two 200 horse-power vertical boilers and one 220 horse-power Ball engine. Three or four baby concentrators for experimental purposes are had. The mill building is 105 feet in height, the extreme height serving for proper arrangement of trommels. (See accompanying photograph.)

Samples of the concentrates and tailings made, exhibit the following features: The best zinc concentrates were made on the table using the $1/170$ to $1/212$ size. These showed at least ten per cent. fluorite, although the same tables had previously produced a product running from 2 to 5 per cent. only of fluorite. The poor showing was probably due to the fact that the mill had not been gotten into proper adjustment, it having made but a few runs at the time of the writer's visit.

Mixed sizes of galena show at least one per cent. fluorite and three per cent. sphalerite. The tailings will run at least 80 per cent. fluorite, 15 per cent. jasperoid, and 5 per cent. sphalerite, with galena almost imperceptible with hand lens.

Two conspicuous features that the mill presents, with the object of obviating difficulties of the problem, are:

(1.) The use of two crushers, four rolls and the first set

of trommels to prevent, to the farthest possible extent, re-crushing anything once becoming less than $\frac{1}{32}$ -inch.

(2.) The use of dry table to prevent the great loss that wet concentration would entail by sliming.

It is possible that the finer product that is below $\frac{1}{200}$ -inch might be handled by first roughly sizing in spitzlutzen, then concentration by sliming tables. Some experiments have been made at the mill on the spitzlutzen plan on a small scale, but so far have not been satisfactory.

Already noted experiments, tending to improve the mill, were made in 1906, but the results are not yet for the public.

Illinois Mills.

THE FAIRVIEW MILL.

This mill is situated at the Fairview mine in Hardin county, Illinois. Its capacity per twelve hours is about 50 tons, in the concentrating section. The fluorspar grinding section is reported to have an output of 18 tons per 12 hours, but is not operated continuously. The mill is run part of the time with one shift per day, and again, when rushed, both day and night shifts are employed.

The problem here presented is to save fluorspar and lead, and put calcite, limestone, quartzite, shale, etc., in the tailings.

The ore in the mine is shoveled into 1-ton cars, which are dumped into $1\frac{1}{2}$ -ton skips. These are raised by a 24 horse-power double drum-gear hoist to the top of the incline, where they are dumped into (1) if they contain limestone and calcite; if containing ore, into (2).

1. A double bin situated between slope and the mill; spouts from this feed open cars which are on a track between the bin and mill.

2. An elevated bin of about 150 tons capacity. From this the ore passes automatically to (3).

3. An inclined shaker screen of $\frac{3}{4}$ -inch perforated metal, 42x30 inches, but on a frame 2x7 feet. That passing through goes by launder to (17). That passing over goes to (4).

4. White-faced rubber Robins conveyor picking belt, 24 feet long and 2 feet wide, travelling at a speed of 24 feet per minute.

- (a) The galena is picked off and goes to (17.)
- (b) No. 1 fluorspar is picked off, and goes to (6).
- (c) Waste goes to (5).

(d) No. 2 lump fluorspar is left on belt going over into car at east end; thence tracked to (32 and 35). Picking belt is operated by four boys.

5. Belt conveyor situated just below (4). By this to cars on west of building, and thence to waste dump.

Fluorspar Section.

6. Blake type, 7x12-inch crusher on north of (4); thence by (7).

7. Bucket elevator to (8).

8. Two rectangular steam dryers, 10x18 feet; return pipes carrying live steam, using steam trap to handle condensation. Steam line is of one-inch pipe placed 4 inches apart, completely inclosed by the steel plates of dryers. Capacity 10 to 12 tons per 10 hours. Each capable of a maximum of 20 tons, though smaller quantity produces best results. Shoveled from this to (9).

9. Bin, 8x10x10 feet, for dried lump; thence by launder to (10).

10. Two Griffin mills, maximum capacity 25 tons each, per 10 hours. To (11). Fluorspar ground to 100-mesh.

11. Bin from ground.

12. Bucket elevator to (13).

13. Two vibrating steel wire screen bolters, 32x56 inches, 82-mesh per inch. Inclination 14 and 17 degrees. That passing over goes to (9), and back into (10), where it is re-ground. That passing through goes to (14).

14. Bins somewhat smaller than (9). On ground floor. By launder to (15).

15. Eight horizontal cam barrel tampers. Barrels average 575 pounds in weight, running from 525 to 575 pounds. Barrels for small shipments are commonly lined with paper. Barrels to (16).

16. Storage house.

Fluorspar and Galena Section.

17. Blake type 9 x 15-inch crusher on south of (5). By launder to (18).

18. By bucket elevator to (19).

19. Bin, capacity 100 tons. By automatic feed to (20).
20. First set 30-inch Allis-Chalmers rolls. To (20½).
- 20½. Bucket elevator. To (21).
21. Trommel with ¼-inch perforations; that passing through going to (24); that passing over, to (22).
22. No. 2, 30-inch rolls. By (20½) to (21).
23. Bucket elevator. To (24).
24. Cooley pattern rougher jig, five compartments, each 2 ft. 7 in. x 4 ft. Grates 3-16-inch. Beds kept 8 to 10 inches deep. First 3 hatches to (23). Coarse lead from No. 1 bed by buckets to shipping barrels No. 2 bed to (26). Nos. 3, 4, and 5 bed products by car to (33 and 36); thence from first three hatches to (25). Smaller particles from (23) to (25), larger, by launder to (26) to (29).
25. Cooley pattern cleaner jig, five compartments, each 3 ft. 5 in. x 2 ft. 5 in. Depth of bed 6 in. Sieves ¾-inch perforations. 1st bed and 1st hatch yield clean galena by bucket to shipping barrel. No. 2 bed and No. 2 hatch to (26). No. 3 bed to (33 by 36), contains still a deal of calcite, possibly 5 to 10 per cent., and a small amount of lead chats. This bed is used ordinarily for product containing zinc, but as No. 6 was out of repair, No. 2 was crowded to catch as much as possible of the sphalerite. Beds and hatches Nos. 4, 5 and 6 produce finer spar; to (34 and 37). This product contains shale and some lead chats, but proportionately less of calcite than those of rougher. End product to waste dump.
26. Sand elevator; to (27).
27. No. 3 or chat rolls, 24-inch; re-crushes and by launder to (26) and then to (28).
28. Double section trommel with 1-16 and 1-32-inch perforations; latter by launder to (30); former, by launder to (29).
29. Cooley sand jig, four compartments; beds 24 x 24 inches. Sieves 3-32 of an inch. 1st bed and hatch yields galena to shipping barrel; second bed and hatch by launder to (26). 3rd and 4th hatches to (34 and 37). 3rd and 4th sieves but little used. End product to waste dump.
30. V-shaped tank, with a rectangular box within, holds about 2 tons. Feeds (31).
31. Wilfley table No. 5: Yields about 250 pounds of galena per day, a very clean product. Zinc partly sent off

with waste. Part of product re-run on machine. Amount sent over table per 10 hours has not been determined. Lead to shipping barrel.

32 and 35. No. 2 lump fluorspar bins. (Reported capacity in excess of 7,000 tons).

33. and 36. Course crushed fluorspar bins. (Reported capacity in excess of 7,000 tons).

34. and 37 and 38. Fine crushed fluorspar bins. (Reported capacity in excess of 7,000 tons.)

POWER.—Mill and mine have power supplied by battery, of three 80 horse-power, horizontal tubular return boilers. Consume about 250 bushels of coal per 10 hours. A Hamil-Corliss engine, 125 horse power, at $\frac{1}{4}$ -inch cut off, and 150 horse-power at $\frac{1}{2}$ -inch cut-off, operates mill. At about ten men and two boys are employed at the mill. The boys were at the picking table. The men were divided as follows:

1 engineer; 1 head mill-man; 3 assistants in mill; 1 hoist-man; 1 man at dryer; 1 at car; 1 at ground bins.

The old mill differed from the above in having a more complete sizing system, using for trommels $\frac{1}{4}$, $\frac{3}{16}$, $\frac{1}{8}$, and $\frac{1}{16}$ -inch perforations, the product going from the rolls to these, and from the trommels to different jigs of Faust pattern, using Hartz eccentric. These were four-cell jigs, partly built double, using one plunger; and partly built single, and two set back to back. No table had been installed. The galena concentrates ran about 74 per cent. pure—that is, contained about $7\frac{1}{2}$ per cent. impurities, $92\frac{1}{2}$ per cent. galena. The new mill was recently partly changed, the cylindrical washer being discarded and the picking belt re-arranged so as to accomplish the same work at less cost.

Height of mill building is 55 feet. It is well to note what change of management is capable of bringing about, when matters are not carefully watched. This mill was started, seemingly, with the end of producing a mill duplicating that at Rosiclare, erected without regard to economics of the matter, nor consideration of the hill at hand, affording a good mill site. Scarcely had the mill been well started toward completion, when the management changed, and with it the mill modified according to the ideas of the new engineer. It had been put in fair working order when the

engineer resigned, and was replaced by a man who had another ideal in view, and accordingly set about at once to reconstruct the mill, at a considerable cost, and that without making changes in character, but merely changes in form; whereas, the former could have been made and the table added without adding an additional section to the mill building. For example, new jigs were built, merely changed in form without any change in the principle of operation or effect to be produced. An actual retrogression was made in the matter of reducing the number of trommels for sizing, and nothing was gained by increasing the number of cells on the jigs, the character of product has not been materially changed from that of the previous mill. Recently, the mill was partly rearranged and for the first time was there any material advance upon change of management.

The galena concentrates of the present mill are reported as averaging 68 per cent. lead, and running $7\frac{1}{2}$ oz. silver per ton. The lead concentrates are shipped in whisky barrels, averaging 1,700 lbs.. The heads are put on the barrels by means of L-shaped brackets which are bolted both to the cover and the side of the barrels.

ROSICLARE MILL.

This mill differs from the Fairview in many respects. The ore is of the same character. The ore is dumped onto a floor from the cage cars, and is shoveled onto an automatically sprayed shaking screen. The oversize goes onto a stationary picking table, where two men pick out and throw into barrows the No. 1 lump for grinding, the nearly solid galena ore; and the waste as far as possible. The barrows are wheeled to the proper bins, the No. 1 fluorspar going partly to the drying bin, partly shoveled onto dryer. The lump in the bin is dried by a fan supplied with heated air from about a 12-inch pipe connected with the boiler stacks. The horizontal sheet dryer is heated with steam applied directly between the plates which are 4 inches apart. The fluorspar is ground in a Griffin mill, and the bolting is effected in an 85-mesh rotary bolting machine, 12 feet long and 2 feet in diameter. Barrel settlers are four in number, and are of the vertical cam type. The product is trammed

from cage to 300-ton bin in mill annex. From this, it is shoveled to chain bucket elevator which elevates it to a Gates gyratory crusher, breaking it to $\frac{3}{4}$ -inch, from which it will go to the first set of rolls, then to the second. The crushed product is then elevated to a Hancock jig 25 feet long and 10 feet high. The jigging box is 4 feet wide and 5 feet high, and contains movable bed, having three sieves, with 1, $\frac{3}{4}$, and $\frac{1}{2}$ -inch apertures. The bed has riffles about 3 inches high, each four inches. Cast iron pieces are used for bedding the largest sieve. At the end of the jig is the water-saving water box. The jig bed is actuated by a three-pointed cam, so that the bed makes a downward stroke of $\frac{3}{8}$ of an inch, a forward stroke of 31-100 inch (toward upper end of jig) and an upward stroke of about one inch. The cam is said to make 600 revolutions per minute. The floor of the annex is of concrete. Overstrom tables will probably be installed shortly, to handle the fines. When visited, the mill was not quite complete, so results can not be given at present. The object of the changes was to increase the capacity of the mill several fold, which it is claimed the Hancock jig is capable of doing, it being desired to put through 150 tons per day.

Power is supplied by a 30 and 90 horse-power engine, taking steam from two 80 horse-power tubular return boilers. These supply steam also to run hoist and pumps. About 6,000 bushels of coal is consumed per month. Day shifts only in mill, while mine has both day and night. Two 3x5 feet cages are employed for hoisting.

The mill which is being replaced consists of three trommels, six Faust pattern jigs, (two roughers, two coarse, a coarse and fine) having a maximum capacity of about 35 tons per day. At this mill, a Lumkenheimer slime table was once in use for saving lead slimes, but was not profitable to operate. The products of this mill are not unlike those secured at Fairview. The tailings, however, are very rich in fluorspar, containing also some zinc sulphide, copper carbonate around chalcopyrite, as well as some native copper.

Fluorspar and lead are barreled as at Fairview. The cleaner lump galena is barreled without milling.

The barreled product is trammed by mule tram (24-inch track) to river. Here they have a small building with

machinery for unloading coal from barge and for loading barrels. They have here a boiler and small hoist. The latter is used in drawing up the tram cars on an incline from the barge with the coal. A drum with brake is used to let down barrels on a skid, which will hold from one to three barrels, on another incline.

The mines have a receiving warehouse at Evansville, near the I. C. R. R. depot, where the barrels are emptied (of crushed fluorspar and lead concentrates) and emptied into railroad cars.

ROBINSON MILL.

The problem here is the same as at the Evansville mill. The ore is brought by mule tram to the receiving floor, 85 feet high, where it is hand-picked partly, and shoveled to (1), the cleaner lumps by launder direct to (2).

1. 6-foot washing trommel, with outside cups, $\frac{1}{2}$ -inch perforations, to (2).

2. Picking belt, 3x18 feet long, of narrow transverse boards with iron sheeting; six spouts are supplied for waste product; use one man here; from (2) to (3).

3. $\frac{3}{4}$ -inch small screen, undersize to (6), oversize to (4).

4. 100-ton, self-feed hopper, to (5).

5. 15-inch New Century crusher, to (6).

6. New Century rolls, to (7).

7. Elevator, to (8).

8, 9, 10, 11. Revolving trommels, $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$ -inch perforations; undersize of (8), (9), (10) to (12), (13), (14), respectively, with the undersize of (11) to (15); oversize from all trommels to (16).

12, 13, 14, 15. Three-cell New Century jig; 22x36-inch cells. Products from first cells, lead concentrates, to bins for market; fluorspar from second cell, and tails from third cell and overflow, except second of sand jigs, which is returned to chat rolls.

16. Impact screen, undersize to (18), oversize to (15).

17. Chat rolls; thence to (19).

18. Receiving tank; thence to (20).

19. Elevator; thence to (8).

20. Ford Table, lead concentrates, to receiving bins; middlings re-run, and tails to tailings dump.

Power is supplied by two 10 horse-power, 20-flue Terre Haute boilers, and an 80 horse-power Armington & Sims center crank engine, using 50 bushels coal per day. A 15 horse-power Fairbanks-Morse dynamo to run electric pump and lights. A 9x9x12-inch Sullivan compressor, supplies air for Little Jap hammer drills. Five men used in the mill.

The galena concentrates run 85 to 90 per cent. galena, with fluorspar and some zinc largely making up the balance. That from rougher, with pieces up to $\frac{3}{4}$ -inch is quite chatty, while that from cleaner is comparatively quite free from chats, showing the inadvisability of using a rougher jig. Fluorite concentrates run 90 per cent. fluorite, balance zinc and rock, practically no galena. Table concentrates of both lead and fluorspar is poor, and tailings rich.

EVANSVILLE MILL.

The problem here is to concentrate lead, which is said to run 6 oz. silver per ton, and fluorspar, largely from limestone, and jasperoid gangue, and at times from quartzite. The ore also contains small amounts of zinc, both carbonate and sulphide, not separable by hand-picking. A capacity of 15 to 20 tons is claimed per day. Four men are employed in addition to the foreman; one at crusher, one at jig one at table, one at boiler and engine.

1. Dumping floor. Wagons dump ore here, and zinc carbonate is picked out as far as possible. By shovel to (2).
2. 12-inch crusher to (3), by launder.
3. Chain elevator, 10-inch cups to (4) by launder.
4. 6-foot washer-trommel, $\frac{3}{4}$ -inch perforation, with outside cups. Oversize to (5). Undersize to (10).
5. Shaking screen 16 x 30 inches, $\frac{3}{4}$ -inch between slits; then oversize to (6); undersize to (7).
6. Picking belt 18 feet long, of narrow transverse boards, with iron sheeting. One man picks out zinc carbonate and worthless gangue to separate bins, balance to end and by launder to (7).

7. No. 2, New Century Crusher, 10-inch, crushing to $\frac{1}{2}$ -inch; thence to (9).

8. Chat rolls, 19-inch, crushes to sands for table, going first to (11).

9. Elevator to (4).

10. Four-cell New Century jig, beds each 24 x 36 inches. Jig used separately for making lead concentrates and fluorspar concentrates. Product of first cell to concentrate bins for shipment, while that of the last three cells is re-run. In running fluorspar, get lead concentrates from first, that from second is re-run and fluorspar secured from the third and fourth. Tailings to tailings elevator, with launder to tailings dump.

11. 24x30-inch impact screen; undersize to (12); oversize to (8).

12. Small tank for sands to (13).

13. Ford table, with ripple strips somewhat altered; makes lead heads, middlings and tails; last contains a deal of fluorspar.

An 80 horse-power Brownell boiler and a 60 horse-power Armington & Sims engine supply power. Water is supplied by pump from double compartment settling pond, with concrete overflow to 4 x 8 ft. water tank, which supplies mill. All machinery, except boiler and engine, are of New Century make.

The galena concentrates average 75 per cent.; remainder mainly zinc, (carbonate largely), and a little fluorspar.

Fluorspar concentrates average 75 per cent.; remainder zinc and rock. Tailings run at least 60 per cent. fluorite; balance zinc, limestone and quartzite, largely latter.

CAVE-IN-ROCK MILL.

This mill was erected by the American Concentrator Company, for the Cave-in-Rock Mining Company in the autumn of 1904.

The problem is concentration of fluorite and galena and to tail calcite, limestone, etc. The ore is hoisted by 12 horse-power Sampson geared hoist to near top of a 52-foot derrick, where it is dumped on (1).

1. Grizzly of 2-inch iron bars spaced about 4 inches apart. Oversize spalled with sledge on breaking floor, 32 feet above the ground, and shoveled back on (1). Undersize to (2).

2. Self feed, V-shaped hopper, about 100 tons capacity. To (3).

3. 12-inch New Century crusher. To (4).

4. First set New Century rolls. To (5).

5. Elevator. To (6).

6, 7, 8 and 9. Trommels, with 8, 6, 4 and 3 mm. apertures respectively. Oversize of (6) to (10); undersize to (7). Oversize of (7) to (11); undersize to (8). Oversize of (8) to (12, 13), undersize to (9). Oversize to (15), undersize to (17).

10. Second rolls. To (5).

11, 12, 13, 14. Five-cell New Century jigs with device for carrying off middlings at end. Beds 24 x 36 inches, sieves 4 to 9 mm. apertures. Lead concentrates off first cell and hutch, middlings from second to (15), fluorspar from third and fourth, middling from fifth to (15). Last sieve product of fourth jig to waste dump.

15. Chat elevator; to (16).

16. Chat rolls; to (5).

17. Hydraulic classifier of spitskasten type, (in the form of concentrically double inverted frustrum of a pyramid, with a launder or trough to carry off overflow at top, and spigots for taking off the classified products near the bottom). There are two rows of spigots, the products from the upper row to go to (18); those of lower row, to (14). Overflow to (19).

18. Two Ford tables: Side jerk tables with wavy, full length ripples. Lead concentrates for heads, fluorspar and zinc for middlings, and calcite, limestone, etc., for tails for these tables.

19. Settling tank. Overflow by launder out of mill to waste; spigot product to (18).

Lead concentrates were not collected. Fluorite concentrates show about 90 per cent. calcium fluoride; zinc, limestone, calcite, and jasperoid make up the balance. The tailings are cleaner than from any of the other mills, showing less than 50 per cent. values, largely fluorite.

The power is supplied by 16 x 60 Atlas boiler and one 44 horse-power Atlas engine. Water is supplied from artificial pond, by centrifugal pump.

MARY MILL.

The Mary Mill was completed in 1906 by the Compton Mining & Smelting Company, at their Mary mine, below Bay City, Pope County, Ills.

The problem presented by the Mary Mine ores is somewhat different from that at most of the other mills, since quartzite forms the larger part of the gangue, associated with fluorspar and galena, and some barite.

The ore is hoisted in round steel tubs, and dumped on (1). The derrick is 65 feet high.

1. Grizzly of 3½-inch round bars placed 5 inches apart; size 3 x 4 feet. Product too large is here broken by sledge. From (1) into (2).

2. Self-feed hopper, 60-ton capacity. At the top it is 18 x 18 feet, the back side 5 feet deep, the front side, 18 feet, making the slope about 60 degrees. Side slopes toward the center are had near the bottom with the angle about 35 degrees; to (3).

3. Washing trommel, 96 x 36 inches, and ¾-inch apertures. A two-inch stream plays upon short lauder connecting (2) and (3), entering the trommel with the ore. To (5); formerly to (4). Undersize by launder to (6).

4. Picking belt, wooden iron sheathed, now in disuse. This picking belt was inclined at an angle of 35 degrees toward trommel. At first as much quartzite was picked out as possible, but it was found impracticable, so entire product now goes direct from (3) to (5).

5. Blake type crusher, 9 x 15. To (6).

6. First elevator, 14-inch cups. Then to (7). (The base of all elevator booths at this mill are surrounded by a trough so that escaping products are caught and conveyed by a launder to a settling trough).

7½. First rolls. Make use of a wedge-shaped block to prevent wear of rolls in center, this scattering ore on either side, permitting them to wear more evenly. To (6).

7. Revolving trommels, 72 x 36 inches; apertures $\frac{5}{8}$ -inch. Undersize to (8); oversize to ($7\frac{1}{2}$).

8. Five-cell Cooley rougher jig, beds $46\frac{1}{2}$ x 30 inches, $\frac{1}{4}$ -inch grates. Hutches, except last, to (9); last to (14). Get lead concentrates off first bed; chats off second to (11); fluorspar off 3d and 4th beds to bins, 5th to (11). A narrow settling tank at end of jig, overflow out of mill, spigots to (9) by launder.

9. No. 2. Elevator. To (10).

10. Six-cell Cooley cleaner jig, with screens of 5, 5, 6, 6, 8, 8, mesh per inch, respectively. Lead concentrates from first cell, barite and lead chats from second; fluorspar from next three, and chats from last. Concentrates to bins, chats to (11). Settling tank at end.

11. Chat rolls. To (12).

12. Third elevator. Then to (13).

13. Trommel, 48 x 36 inches; two screens, $\frac{3}{8}$ and $\frac{1}{4}$ -inch; undersize of former to (14), of $\frac{1}{4}$ -inch to (16).

14. Cooley sand jig, 4 cells. Lead concentrates from 1st cell; chats from 2d to (11); 3d fluorspar to bins; 4th, same, only occasionally being too poor, when it is sent to waste dump by launder. Settling tank also at end of this jig.

15. Classifying tank, with rectangular inner box for classifying. Size of tank 3 x 12 feet. Overflow out of mill, spigots to (16).

16. Wilfley table. Use wooden strip on side beneath and perpendicular to surface of table to separate lead from zinc barite chats. Latter separated from spar by triangular block, also perpendicular to table, and last tails separated by strips as in first instance. Get as high as 300 lbs. of galena per day. Get 500 lbs. fluorspar off of table.

Power is supplied by 110 horse-power locomotive type boiler, and one 80 horse-power tubular return boiler, bricked in. Use three tons of coal per day and night, running mill only on day shifts.

Out of 40 tons of mine-run ore, 23 tons of fluorite and 2 tons of galena were secured. The lead concentrates are fair, barite being the principal impurity; the last are reported to have run 74 per cent. lead and eleven ounces silver per ton. It is remarkable that, with quartzite gangue, there should be

produced so small a percentage of slimes as is the case at this mill. The fluorspar concentrates run about 90 per cent. fluorspar, with limestone and zinc forming most of remainder. Finer fluorspar concentrates show, as is to be expected, high in quartzite and low in limestone, etc. Tailings are remarkably clean, consisting of about 80 per cent. quartzite, fluorspar making up most of remainder.

The ore is trammed out of mill at present directly to bins which are outside; four have a 30 ton capacity; one 50 ton, and the other 100 ton. A turn table is provided above first tank, reached by tram so the car may go to bins in either direction. The spouts from the jig beds have been arranged so as to feed the car directly as far as possible; but it is proposed to change this so that launder will carry products direct from jigs to ore bins, and thus do away with tram. It is also proposed to build an elevator to load wagons automatically, instead of shoveling from bin spouts, as at present.

PIERCE MILL.

The Pierce Mill, operated by the Pierce Fluorspar Company, is situated at Golconda, Pope County, Illinois.

The problem is to clean highly crystallized colored fluorite, occurring in residual red silicious clay, of clay and silica

The product is hauled 17 miles from the Hubbard mine, and dumped on a platform, and thence shoveled to (1).

1. Williams crusher. To (2).
2. Elevator, 6-inch cups. By launder to 1st bed of (3).
3. Three-cell Cooley jig. Fluorspar secured from all three beds and shoveled onto (4). Hutch product, fine fluorspar, more silicious than the bed product, is wheeled on to dump, where it is accumulated to be re-run.
4. Direct-heat horizontal dryer, fired at both ends. Product shoveled onto (5.)
5. Formerly used horizontal steam dryer. Shoveled to (6.)
6. Williams pulverizer. To (7.)
7. Inclined 50-mesh bolting screen; the 70 per cent. product, it is claimed, will pass 100-mesh. To barrels. Have one horizontal barrel settler.

Power supplied by two Lancashire boilers and one 80 horse-power engine, which also supplies power for a saw mill. Water is supplied from a backwater slough by a Fairbanks-Morse duplex pump.

Since but little of the product that goes through mill is lost in washing, the difference in cost of hauling is immaterial had mill been erected at mine; whereas the cost of power would have been much greater.

A capacity of 20 to 25 tons is claimed per ten hours, though it probably does not exceed half that amount.

Two grades, No. 1 and No. 2 ground fluorspar, are made. At the writer's last visit the product was largely of second grade. The jig makes only a fair product, as the silica content is said to run 1.25 per cent. The use of screens and another jig would permit the silica in the larger sized product to be much reduced.

General Results and Conclusion.

The various mills show practically the same results in a general way, though some of them come nearer solving the problem in hand than do others. These results briefly are:

Presence of fluorspar or zinc with the galena, usually in the form of fines, partly in form of chats; fines especially in jigging in the lutch product, chats more often in the bed product, and in sized particles on tables. The presence of these minerals as fines could largely be remedied by a greater vertical action of waters from below the bed up through it in the jigs. Fewer chats may only be had by finer crushing of the agglomerated particles.

The association of a small percentage of lead and calcite, with a larger percentage of fluorspar, with the zinc after concentration. This percentage has been reduced by some of the mills to from 3 to 5 per cent., or less, of fluorite; still more than that is desirable.

Five to ten per cent. of calcspar, limestone, quartzite, shale, together with a little lead and zinc, is found in the fluorspar concentrates, so that they usually must be classed as No. 2, and occasionally as No. 3 product.

The presence in the tailings of a large percentage of zinc values with little or no lead, and a large or small percentage

of fluorspar, depending on as to whether the ore be as (1) or (2).^{*} Likewise in (3) a large percentage of fluorite, 60 to 75 per cent. in the tailings. Four (4) presents a somewhat less content in the barite concentrates, and a large percentage of both in the tailings, while (5), showing practically no difference in specific gravity of minerals, can not be considered by gravity methods.

The third problem becomes less difficult, if a small amount of hand picking be done to rid most of the calcite from the ore, as is now generally the practice, when fair galena and fluorspar concentrates are secured. In fact, the calcite may largely be eliminated by hand picking from all the other types, at a small cost.

In the writer's opinion, dry sizing will be more efficient for the products where finally ground; but, after such sizing, the separation will be as effective by wet methods as by dry ones. The coarse products may be handled by jigs, and the finer ones by tables, spitzluten and sliming tables, in the wet method.

^{*} The numbers in parenthesis refer to the "five problems" in concentration named under Ore Dressing Problems on a preceding page.

CHAPTER VI.

THE USES AND TECHNOLOGY OF FLOURSPAR.

The uses of fluorspar may be grouped according to its natural characteristics under five heads:

1. Depending on chemical composition: Manufacture of hydrofluoric acid; other fluorine compounds.
2. Depending on fluxing and detergent properties:
 - a*—In metallurgy of iron, steel, aluminum, manganese, gold, copper, lead, tin, nickel, etc. and their alloys; in the production of alundum (artificial corundum.)
 - b*—In the manufacture of glass: Common, plate, opaque, and opalescent.
 - c*—In the manufacture of enamels, glazes and fireproof ware.
3. Depending on optical properties: Apochromatic lenses.
4. Depending on structure and color: For ornamental purposes; gems, cheap jewelry, vases, paper weights, etc.
5. Depending upon its volatilization and phosphorescence upon heating: Carbon electrodes for flaming arc lamps.

Besides, it was formerly used in the manufacture of Portland cement, to bring about an easy clinkering in the kiln; a practice which Mr. E. C. Eckel, an able authority upon cement manufacture, states has been discontinued and is not again likely to be resumed. A small amount of low grade gravel fluorite has locally been used, also, as a grouting for cement. The objection to the use of fluorspar in cement manufacture may be overcome, were basic linings substituted for the commonly used acid linings of the kilns; and the use of small quantities of fluorspar ($\frac{1}{3}$ to $\frac{1}{4}$ of one per cent.) would be beneficial not only in bringing about an easy clinkering of the cement ingredients and lowering their fusing or sintering temperature, but also in eliminating the sulphur present either in sulphuric acid or in

calcium sulphate, sulphur being highly objectionable since it permits a slower setting of the cement, prevents it from becoming hard, and causes disintegration.

Fluorspar has been but sparingly applied for the uses named under the third, fourth and fifth headings in America; the quality necessary for use under the third heading is rare, while there is an abundance of the grades suitable for that under the fourth and fifth headings.

About 20 per cent. of the crude fluorspar is marketed in lump form, the remainder as gravel. Of the total fluorspar consumption fully 80 per cent. is used in iron and steel-making, chiefly in open hearth charges; 5 per cent. additional by other smelters. A small per cent. of the lump and gravel (the crushed is included with latter) is purchased by manufacturing chemists, enamel-ware makers and founders. From 10 to 12 per cent. is consumed in the ground form. Of this, the chemical (largely hydrofluoric acid) and glass industries consume 57 and 21 per cent. respectively. The consumption of ground for glass purposes shows an increase over previous years. Of the remaining ground consumption, 13 per cent. goes to the manufacture of enamels, glazes and fireproof ware, about 5 per cent. to founders including ground used otherwise by metallurgists, and the remainder for miscellaneous purposes. The enamel people are using less in the ground form and more lump than formerly. About 135 companies use fluorspar in greater or less quantity for the several uses, and in addition there are several hundred iron, steel and brass founders using it in small quantity. A number of products, such as "Iron-flux," "Fluorine," etc., consisting either wholly or partly of crude or ground fluorspar are on the market and being sold to the founders at a higher price than fluorspar, for use as flux. One company sells a flux consisting largely of fluorspar, limestone, red clay and certain additional secret chemicals. The red clay, consisting largely of iron oxides with alumina, probably acts akin to thermit in assisting to reduce the fusing heat.

The Western Kentucky district has exported ground fluorspar both to Canada and Mexico, while crude fluorspar is also shipped the former. German consumers have sought quotations on Kentucky fluorspar in quantity, although in

excess of 15,000 tons of fluorspar was exported by that country in 1905, largely to Austria-Hungary and nearby countries.

The Manufacture of Hydrofluoric Acid.

Hydrofluoric acid (HF) is made by decomposing or distilling, in cast iron vessels, the best ground fluorspar with concentrated sulphuric acid. The reaction involved is $\text{CaF}_2 + \text{H}_2\text{SO}_4 = 2\text{HF} + \text{CaSO}_4$. This reaction will take place at ordinary temperatures, although complete decomposition is effected only at 130 degrees C. or above. The acid is evolved as a vapor. The gas dissolves in water with the evolution of considerable heat, forming the compound $\text{HF} + \text{H}_2\text{O}$. Commercial acid contains from 30 to 60 per cent. water. Weak acids, containing from 30 to 35 per cent. HF, are shipped sometimes in barrels, while the higher grades are marketed in lead or gutta percha vessels.

Following is a description of the manufacture of the acid on a large scale, given by Mr. Anson G. Betts in the *Engineering and Mining Journal*, vol. 83, page 753:

"The pot may be cast about 8 feet in diameter, 3 feet deep at the center, and 1 inch thick, with a slightly curving bottom to prevent cracking. For the pot a cast iron cover 1 inch thick is used, dipping into the annular trough around the pot, which contains strong sulphuric acid as a seal. All the other seals are made in the same way, but water may be used for the joints on the condensers where the temperature is not so high. Lead retorts, and lead covers for the retorts, are useless.

"The condensers consist of a series of two or three lead boxes of about 1 cubic meter capacity, entirely submerged in a water tank and partially filled with water or diluted HF. Condensers should be made of heavy lead, supported by wooden pieces to which the lead is attached by means of lead straps burned on. The lead delivery pipes may be about 5 inches in diameter. The condensers have an overflow so that the acid never can rise to the end of the delivery pipe. If this happened, a partial vacuum might result and draw water back into the pot, where it would probably cause an explosion.

“The charge may consist of 1,000 lbs. of ground fluorspar and 1,000 to 1,200 lbs. of 66 deg. sulphuric acid. SiF_4 comes off first and deposits silica on the water in the first condenser, stopping absorption somewhat, so that it is necessary to stir the water in the first condenser until most of the SiF_4 has come over. The pot may be charged in the morning and distillation finished by night. Coal is used for fuel, burned on grate of about 3 square feet. The residue in the pot is comparatively hard, and, after cooling, is dug out with pick and shovel. The yield of acid calculated on the sulphuric acid used is approximately 80 to 90 per cent.

“The cost of manufacture is not great, the principal items being the raw materials necessary. To produce 1 pound of anhydrous HF , about $2\frac{1}{2}$ lbs. of fluorspar and 3 lbs. of sulphuric acid are necessary. Fluorspar and sulphuric acid are worth about \$10 to \$15 a ton, making a cost for raw materials, exclusive of coal, of approximately $2\frac{3}{4}$ to $4\frac{1}{2}$ cents per pound of anhydrous hydrofluoric acid.”

Mr. Betts also gives a method of preparing the acid for laboratory use on a small scale:

“For preparation in small quantities for the laboratory the following gives good results if used out of doors. The retort is an ordinary cast-iron pot, perhaps one foot in diameter and 6 inches deep. The cover is made by filling with sand to near the top, leveling it off and pouring in about $\frac{1}{2}$ -inch of lead. The lead pipe is separated from the cover, and passes over to a lead hydrofluoric-acid bottle containing water. The water must not come as high as the end of lead pipe.

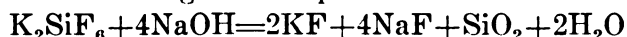
“During distillation, the bottle is sprayed with water from a hose to keep it cool. A charge of about 2 kg. of fluorspar and 2.5 kg. of sulphuric acid of 66 deg. is stirred up in the pot. The fluorspar, for the most part, dissolves immediately on stirring in the sulphuric acid, without evolution of much fume, until heat is applied. The cover is put on and dry cement put over the joints as a lute, cement being suitable for this purpose.

“The heating should be moderate at first to prevent too much frothing in the pot. Distillation takes 2 or 3 hours, and the end can be told by feeling of the lead pipe near the bottle,

which is hot as long as acid is coming over. Very little loss is experienced and a yield of 80 per cent. or thereabout is obtained."

The principal impurity of hydrofluoric acid is fluosilicic acid, and it is most important that the commercial acid be almost free from this substance, as the value of hydrofluoric acid for most purposes depends upon the facility with which it combines with silica.

Analysis of the Acid.—Mr. Betts presents the following method for determining the quality of the acid: "The sample of acid is mixed with several times its bulk of nearly saturated and neutral potassium nitrate solution. This causes a precipitation of potassium fluosilicate in the solution Phenolphthalein is used as indicator and the solution titrated with caustic soda in the cold. This gives the total of the HF and H_2SiF_6 present. The sample is then heated to boiling when it will be found that considerable more caustic soda may be run in to get another end point. In the first titration, the HF present and the HNO_3 liberated by the reaction of potassium nitrate and fluosilicic acid, are neutralized by the alkali. When titrated hot, the precipitated K_2SiF_6 is decomposed by the alkali. The following is the equation involved:



"The rule for calculating is, 1 gram NaOH used in the second titration equals 0.9 gr. H_2SiF_6 in the sample. For HF present divide the number of c. c. of NaOH used in the second titration by 2, and subtract the result from the c. c. used in the first titration. The remainder shows the HF, 1 gram of NaOH equaling 0.5 gram HF."

To make pure acids it is essential that manufacturers use fluorspar carrying only a small percentage of silica, less than one per cent. at most. Analyses of English samples show 3 per cent. of fluosilicic acid, the best grade German in six samples from .1 to .7 per cent. while the best ground of American production is equally good or better than the German. It is also advisable to use white fluorspar, since the colored varieties contain more hydrocarbons which increase the impurity of the acid. By heating the fluorspar to the point of decrepitation previous to its distillation with sulphuric acid, not only will the fluorspar be freed from hydrocarbons, but

will permit of the separation of most other impurities by screening, the undersize being the pure powder. This, since silica, gypsum, etc., are found mostly in granules which are not reduced by the heat. It is necessary that the heating be done quickly. The increased fineness of the pure fluorspar will permit the digestion of a larger per cent. of fluorspar in the process of distillation, increasing the yield of hydrofluoric acid. The best grades are obtained from deposits that occur in limestones containing only small quantities of silica and carbonaceous matter. Fluorspar mixed with carbonates as calcite, etc., is also undesirable, since the sulphuric acid combines with them forming sulphates, increasing the consumption of sulphuric acid otherwise necessary in making HF. The main use for the acid is in etching glass, though in recent years the demand for it for cleaning old brasses, etc., is increasing. About 7 per cent. of the fluorspar consumed in America is consumed in the manufacture of acid.

In regard to the use of hydrofluoric acid for cleaning castings the following, from *Iron Age*, Nov. 8, 1906, is of interest:

"Hydrofluoric acid as a cleaning agent for castings has been in general use but a short time, being treated a few years ago as a secret process by those who understood its value and made use of it in removing the clinging sand. Formulas for the acid containing superfluous and innocuous ingredients to mystify the purchaser have been sold for considerable sums. Anything used in connection with this 'pickle' aside from the hydrofluoric acid and water, is wholly unnecessary, the usual formula being 1 part of acid to 10 parts of water. In adding water, however, care should be taken to know the strength of the raw acid, as this is by no means uniform. The idea is to get a dip that will remove the sand perfectly and quickly, the operation requiring ten to fifteen minutes, depending upon both the amount of sand to be removed and the condition of the pickle."

The same precautions should be used in the manufacture of acid for this purpose as that for glass etching, since the object in both cases, the removal of silica, is the same. The more dilute acids may, however, be employed for this purpose;

for example, if 30 per cent. (equivalent to 30 per cent. pure acid in solution in water), one part is used to three parts of water.

Chemically pure acid should be prepared in platinum vessels, as even lead vessels are attacked, though feebly. After a coating of sulphide and sulphate forms on the lead, the action completely ceases. This quality is used largely by the analyst. It is shipped either in ceresine or platinum bottles.

To a considerably less extent, fluorspar is used in making other fluorine compounds used by the chemist.

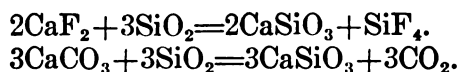
Fluorspar in Metallurgy.

The use of fluorspar in metallurgy was first mentioned in 1529 by Agricola, who gave the mineral its present name (from Lat. *fluere*, to flow) owing to its quality of rendering slags fusible at a low heat. Silica, sulphates of lime and barium, and other refractory substances can be readily fused into homogeneous masses, but it shows little tendency to dissolve basic oxides. One part of fluorspar will liquefy about one-half part of silica, four parts of calcium sulphate, or one and one-half parts of barium sulphate. Upon these principles its wide application as a flux was based.

Until the beginning of the last century it was considered practically an indispensable flux for the reduction of the various metals. The improvements attained by blast furnaces and smelting apparatus permitted the use of cheaper fluxes. As fluorspar serves not only as a flux, but as a detergent or cleansing agent as well, the cheaper fluxes can not take its place. Its use has been constantly increased since 1880. In this country, 85 per cent. of the fluorspar consumed is used in smelting and fully 80 per cent. in the iron and steel industries, considerably the larger percentage of which goes into open hearth steel charges.

Iron and Steel.—In the metallurgy of iron and steel, fluorspar is used principally for the purpose of carrying the silica, sulphur and phosphorus into the slag. The use of fluorspar also effects a saving in the quantity of fuel necessary for the reduction of the charge, perhaps by the liberation of heat in the production of fluosilicate in the slag; and perhaps, also,

since it permits the melt to be made at a lower temperature, having a greater fluxing power. Other beneficial effects of its use, are an increase of 3 to 5 per cent. in iron output and the better quality of material produced. According to Foehr, the reactions involved in the fluxing of the silica in iron ores, by the use of fluorspar and limestone respectively, are as follows:



The quantitative economy of the two fluxes is in proportion of 156 to 300, but in practice the economy is often much greater than this, as one part of fluorspar at times goes further than ten parts of limestone.

The quantity of fluorspar used for flux is only one half of one per cent. of the quantity of lime stone flux consumed, and while the ratio of increase in the use of fluorspar as against limestone since 1902 is small, yet it is sufficient to show fluorspar is materially gaining in favor. Fluorspar analyzing from 50 to 60 per cent. and higher in calcium fluoride and with the silica content as high as 8 per cent. has been used in these industries. The use of 85 to 95 per cent. fluorspar and with the silica content no higher than 3 to 4 per cent. is most economical in steel-making. For ordinary irons lower grades may be readily used. Furnace linings made of chromite are said to be but little affected either by volatilized fluorides or fluorine in the slag. With the assured supplies of fluorspar in the Kentucky and Illinois districts, which are accessible to transport by rail and water to the large iron and steel centers, it is believed that the use of fluorspar in iron and steel metallurgy will show a constant increase in the future.

Open Hearth and Bessemer Steels.—In the open hearth steel furnace, fluorspar is used mainly in the basic processes to make a more fluid slag, also to prevent the slagging of the phosphorus and to reduce the sulphur content.

The procedure in the use of fluorspar in the production of basic steel in the open hearth furnace as given by an experienced operator* is as follows:

*Kerr, J. W. L., private communication.

"Magnesite and dolomite for furnace linings is first put in the slag, after which 6.5 tons of limestone flux and 25 to 35 tons of scrap iron is added and the whole heated together. When at the right heat the melted pig iron necessary to make the charge total 60 to 70 tons is brought in. Lake Superior hematite is then added till the carbon content is reduced from .18 to .08 per cent. Pieces of limestone come to the surface in blocks, fluorspar being used in amounts varying from 200 to 1,100 pounds or about .15 to .8 per cent. per charge, both to break up the blocks of limestone flux and to reduce sulphur and phosphorus content."

One of the largest users of fluorspar for open hearth steels informs the writer that they are unable to use fluorspar that runs as high as 15 per cent., and prefer it to run not higher than 12 per cent. silica. About one-half of the fluorspar purchased by this company does not contain over 5 per cent. silica.

In the making of open hearth steel castings the function of fluorspar is to thin a limey slag when in the judgment of the melter it seems thick or sluggish. A moderate addition of fluorspar will liven it and its action may be likened to certain fluxes used in brazing metals, the property of dissolving at lower temperatures the metallic oxides. In the production of one net ton of castings in basic practice Carr* states 13 pounds of fluorspar are used in addition to 300 pounds of limestone for flux, to 1,227 pounds each of pig iron and steel scrap. In American practice he says 5 pounds of chrome ore are used per ton for patching parts of the hearth where cutting above the slag line is severe upon the brick work, usually in gas ports and door jambs. Aside from patching, it is used as a neutral lining between magnesite and silica bricks. In European practice it is stated that entire hearths are lined with lump chrome ore.

A basic lining, the patent for which is held by Westinghouse, consisting of basic substances as magnesite, chromite, and chromic oxide, or the like, with water glass (sodium silicate) and calcium chloride, would probably be suitable for basic linings where fluorspar is used.

* Carr, W. M., in *The Foundry*, Vol. XXVII, No. 4, 1905, p. 106.

In open hearth practice, fluorspar is of particular value in permitting the use of an increased proportion of scrap iron. In one of the Western Pennsylvania plants, a charge of 50 tons of cheap scrap, when melted with 2,500 pounds or 2.5 per cent. of fluorspar is said to give as fine steel as the best pig.*

Henderson, in an experiment in an ore lined open hearth furnace using cast iron, added 3.6 per cent. fluorspar; through its agency the phosphorus content was reduced from 1.14 per cent. to .17 per cent., the phosphorus partly volatilizing and partly going into the slag.

In the Bessemer process, according to Howe, the phosphorus leaves the iron rapidly during the early part of the operation. This has been ascribed to its effect in fluxing the lime present and rendering the slag effectively basic; without fluorspar, it is thought that the lime melts and combines with the slag but slowly.

Dr. Foehr† states that in both the Bessemer and Thomas processes (in acid and basic steels), fluorspar is used in small quantities to concentrate the slag, and reduce the loss of metal. Where acid linings are used care must be taken to prevent the slag containing the fluorine from attacking them. It is also used in puddling in the various steel-making processes.

Howe, in his "Metallurgy of Steel," commenting on experiments of Henderson and Percy, says that apparently under strongly oxidizing conditions like those of the basic Bessemer process, phosphorus tends rather to form calcium phosphate than phosphorus fluoride. Under gently oxidizing conditions of the open hearth it forms fluoride. To sum up, fluorspar or calcium fluoride appears to favor dephosphorization:

"(1) By liquefying the slag, thus enabling it to assimilate the lime present, part of which might otherwise remain unmolten and inert, and thus rendering the slag effectively basic.

"(2) Probably by volatilizing silicon from the metal, thus diminishing the formation of silica and thereby increasing the basicity of the slag.

* The Mineral Industry, Vol. XIII, p. 153.

† Mineral Resources, U. S. Geological Survey, 1888-1890, p. 460.

“(3) In certain cases, that is when conditions are not strongly oxidizing, by volatilizing phosphorus as fluoride.”

Mr. Randolph Bolling recently devised and worked out the following sufficiently accurate and rapid method of analysis of fluorspar for open hearth steel works:*

“A 1 gm. sample of the fluorspar, which had been well ground in an agate mortar, was heated in a 30 c.cm. platinum crucible with 10 c.cm. of strong sulphuric acid over a Bunsen burner, with an asbestos plate so as to reduce any tendency of spurting. After all the fumes had ceased, the crucible was allowed to cool, 5 g. of sodium carbonate were added and the crucible was brought to a red heat over a blast lamp. After complete fusion the mass was run up the sides and the crucible was finally placed in a 500 c.cm. porcelain casserole with enough hydrochloric acid of 1.10 specific gravity to cover it, and evaporated to dryness, the crucible being removed, of course, after the fusion had dissolved. It was then taken up with strong hydrochloric acid and water was added to dilute the strong acid, so that it would not destroy the filter. It was then treated exactly in accordance with the standard scheme for limestone analysis. The silica was removed and determined by the first filtration, the iron and alumina were precipitated by ammonia, filtered and weighed, and then fused to estimate the iron. The filtrate from the iron and alumina contained all the lime, which was precipitated as usual by ammonium oxalate and determined by the standard permanganate solution. Magnesia is usually present in so small an amount as to be excluded from examination, but can, of course, be determined in the last filtrate. As calcium carbonate is sometimes found in foreign fluorspar, a determination of CO_2 by the usual method as is used for limestone is made on a separate sample, except that tartaric acid is used instead of mineral acid. In calculating the results, the CO_2 is combined with enough lime to satisfy it for the CaCO_3 formula, and the remainder of the lime is calculated to calcium fluoride (CaF_2 .)

* Iron Age, Nov. 8, 1906.

“A typical sample of English fluorspar gave the following result:

Calcium fluoride	78.4 per cent.
Calcium carbonate	8.1 per cent.
Silica	4.2 per cent.
Alumina	0.5 per cent.
Oxide of iron	1.0 per cent.

“This scheme of analysis is quite satisfactory for a works laboratory. In the analysis of samples from prospecting, the determination of fluorine directly, according to Fresenius, would be necessary when one is not sure of the source of the sample. This is quite intricate, and is rather difficult to carry out without special equipment. In the above method care must be taken to drive out all sulphuric acid in the initial treatment, by heating to a low red heat before fusing with sodium carbonate. Other elements accompany fluorspar, such as traces of phosphorus, manganese, sodium and potassium, but as these are merely of scientific interest their estimation would not be of any special value and, therefore, can be omitted.”

Wrought Iron.—In the puddling furnace, Henderson employs a mixture of titaniferous iron and fluorspar, whereby fluorides of phosphorus, silicon, etc., are said to be evolved and slags abnormally free from silicon and phosphorus were derived. By this process, which shows a more rapid purification than ordinary puddling, original pig showing 1.14 per cent phosphorus, the phosphorus content in 30 minutes were reduced to .23 per cent., in 50 minutes to .12 per cent. and the final wrought iron showed only .07 per cent. As the resulting cinder showed less phosphorus than was in the pig employed, apparently some amount of phosphorus was volatilized as fluoride.*

Iron and Steel Alloys.—Fluorspar is used in the production of manganese and silicon alloys, and it is known that a company manufacturing ferro-chrome also uses it; it is probably used in making other alloys also.

*Encyclopedia Britannica, Ninth Edition, Vol. 13, p. 820.

The production of a basic slag which in fluorides is necessary in producing manganese steel, spiegeleisen, and ferro-manganese; for the last it is absolutely necessary.

Ferro-silicon, containing as much as 10 per cent. silicon, can be obtained in the ordinary blast furnace from any silicious iron ore, producing a basic slag, if it be fluxed with fluorspar. The fluorspar energetically reduces the silicon; at all events, fluorsilicon is formed, which is reduced to silicon by the hydrogen contained in the furnace gases, and possibly also directly by the coke.

Ordinary and Foundry Pig.—Owing to its high price, its use in the manufacture of gray and white pig is limited, although it is an energetic solvent in blast furnace work, when blown as a powder into the nozzles. Its carrying phosphorus into the slag is not of much benefit in making ordinary pig iron. It is, nevertheless, used in the Krupp and Rollet processes of dephosphorizing pig in the basic lined cupola furnace. Foehr thinks that in this process it only serves as a flux for the basic lime slag saturated with phosphorus.

A very small quantity of fluorspar in the manufacture of foundry pig will reduce both quantity and cost of fuel (coke), producing, as it does, a No. 1 deep gray pig, rich in graphite, permitting also the use of lower grades of iron ore, and the use of higher percentages of scrap; and in this also to reduce the phosphorus and sulphur content.

Limestone flux in cupola furnace work serves only to slag the ashes of the fuel, the sand adhering to the pig, etc., no chemical effect being produced on the iron. The fluorspar, as already noted, produces a chemical effect on the iron by not only carrying phosphorus and silicon into the slag, but also by keeping the silicon as an alloy, and making the iron gray and soft.

In the foundry cupola, only $\frac{1}{3}$ to $\frac{1}{2}$ per cent. (6 to 10 pounds per ton of charge) fluorspar is to be used, as over $\frac{1}{2}$ per cent. would tend to have the manganese contained in the iron to slag. It is made into a paste with water and spread upon the bed of fuel just before charging the iron in the furnace. In other cases, as noted above, a considerable greater per cent. can be used to advantage, this depending

entirely on the quality of the iron to be produced. The improvement of the product caused by this flux is especially manifest in the improved cupola furnaces, especially the Herbert, and has facilitated the use of inferior iron for soft castings.

In an article in *The Foundry* for January, 1905, N. W. Shed gives the results of some tests made by the Foundrymen's Laboratory of Buffalo. A thousand pounds of fluxing fluorspar, sold under some high sounding trade name, was used in the test. It was partly as fine as coarse sand and contained some crystals. The tests were made in one of the cupolas of the Buffalo Foundry Co. The results of these tests are presented immediately below, while following them are statements more favorable to the use of fluorspar by other recent writers. Mr. Shed says:

"To answer the claim that the flux would remove sulphur, Bessemer pig iron, averaging .044 sulphur, was taken. This pig was machine cast and very clean. In order to remove the possibility of introducing unknown amounts of sulphur, no scrap was used.

"The coke was sampled from several cars and found to run very even, the average sulphur being 0.75 per cent.

"The scheme followed was to run one day with the flux and use the same pig and coke with lime the following day.

"The first day, 8 lbs. of flux were used to 1 ton of iron, adding 20 lbs. of limestone, so that each charge of 3 tons of iron had 24 lbs. of fluorspar and 60 lbs. of limestone. The following day, 120 lbs. of limestone were used and no flux.

"The cupola used was a Whiting, 66 in. diameter. The castings were ingot molds, bottom poured. The sprues from each mold were drilled. The results:

Using Fluorspar.

	Sulphur
1st day -----	.094 per cent.
3d day -----	.094 per cent.
Average -----	.094 per cent.

Using Limestone.

	Sulphur
2d day -----	.100 per cent.
4th day -----	.090 per cent.
Average -----	.095 per cent.

Loss of sulphur due to flourspar, .001 per cent.

"This is practically nothing, and shows that the flourspar, 8 lbs. to the ton, has no effect in reducing sulphur.

"On the fifth day, the maximum amount of flourspar was used, 15 lbs. to the ton. The producers of the flux caution foundrymen against using a greater quantity on account of its cutting action on the cupola lining. No limestone was used with this amount of flux.

Results:

	Sulphur
5th day -----	.089* per cent.
With flux -----	.091* per cent.
Average -----	.090 per cent.

*Duplicate analyses.

	Sulphur
6th day -----	.093* per cent.
With limestone -----	.091* per cent.
Average -----	.092 per cent.

*Duplicate analyses.

"Loss of sulphur due to flourspar, .002.

"This is a very small amount and might be due to a variation in the coke as much as to the influence of flourspar.

"When limestone was used with flourspar the cinder was fairly fluid—it was necessary to pull it away with a hook occasionally.

"When limestone alone was used, the slag was perfectly liquid and no hook was needed.

"On the fifth day, when 50 lbs. of flourspar were used, the slag was very sluggish and stringy. The cupola bottom was in bad shape the next morning, masses of iron, coke and cinder stuck to the sides of the cupola, requiring bars and sledges to break the tough cinder enclosing them.

"On the sixth day, when limestone alone was used, the cupola was clean, no barring or sledging being required.

"The claim that phosphorus is removed is of little importance to the foundryman, for it is rarely that the founder wishes to reduce phosphorus, in fact he generally wishes to increase it. With a glassy silicious cinder, it is impossible to remove phosphorus. If the cinder should have an excess of lime as the basic open hearth cinder has, then it is likely that fluorspar would remove phosphorus.

"To practically test the claim of phosphorus removal these tests were made:

	Per cent.
Phosphorus in Bessemer pig used-----	.095
Using fluorspar; phosphorus-----	.110
Using limestone; phosphorus-----	.100

"This shows that no phosphorus is removed by the fluorspar flux.

"The cost of fluorspar should be considered. The lot of 1,000 lbs. cost \$17; this is \$34 per net ton. By car-load fluorspar ought to be delivered in Buffalo for \$12 per ton.

"Limestone, which is an equal fluxing value to fluorspar, can be delivered for less than \$2 per ton.

"Foundries near the great Kentucky-Illinois deposits of fluorspar would probably find it an advantage to mix fluorspar with limestone, for at such points fluorspar could be obtained at very nearly the same price as limestone. At this distance there seems to be no practical advantage in the use of fluorspar.

"There was no indication that the iron was more fluid by using the flux. But to accurately test this and also the claim that iron is stronger will be the subject of a further investigation by the Foundrymen's Laboratory.

"To sum up the results of these experiments it will be found that:

- "1. Fluorspar will not remove any sulphur.
- "2. Fluorspar mixed with limestone makes a fairly good flux in the cupola.
- "3. Fluorspar used alone makes a very poor flux in the cupola.
- "4. Fluorspar cleans the iron no better than limestone.
- "5. Fluorspar does not remove phosphorus.

"By previous trials it has been found that limestone mixed with the coke will reduce the sulphur two or three hundredths per cent, so that the statement that limestone is a better all-around flux than fluorspar is fully justified."

R. C. Hill in *The Foundry* for May, 1905, gives the results of tests made by him in connection with the use of fluorspar, reaching the conclusion that fluorspar improves in every way both gray and malleable iron, also brass castings. He says:

"We find on looking into the use of this flux in the foundry line that possibly many of the users of fluorspar are not aware that one of the most valuable methods of using this article is by putting a small quantity in the bottom of the ladle, then drawing the molten iron upon it, thus facilitating the mixing of the flux with the metal.

"I, personally, have made several experiments which have brought about satisfactory results. For instance, one of my tests in gray iron was to put in the bottom of the ladle 3 per cent. of ground fluorspar, drawing the molten iron upon it. By the time the molten metal had reached the mold with the ladle, the excess slag was quite apparent, rising to the surface and forming a heavy mass, which he stirred a half minute in order to be sure of a perfect mixture and then skimmed off. This shows the powerful action of this material upon iron. We poured two test bars from this ladle. We also poured two bars from the regular iron. These bars, when broken by a breaking test machine, showed that the bars in which the flux was used showed 11 per cent. greater breaking strain.

"In malleable iron, the test was even more interesting. I sent four regulation rods, two with and two without the flux, to a university that professed to be very much interested in this line of work, and upon which I knew I could depend for a fair test. In fact, nothing was known about the material which was being tested. The report received from them showed, in round numbers, an increase from 55,000 lb. tensile strength to 60,000 lb., and an increase in elongation from 4 to 5 per cent.; this, of course, proving the superior malleability of the bars in which the flux was used. I sent some of this material to a firm who are making frogs. They reported satisfactory results. At the time I sent this, I knew nothing of

their trouble, but they told me that it prevented, to a large extent, cracking, with which they had had a great deal of trouble. My own experiments so far have met with the same success.

"I have also made some experiments with fluorspar in brass; it has increased the strength of the metal and given better results in the finished casting.

"You have noticed in the above that I have given no chemical analysis; the reason for this is that I consider the results will speak for themselves, but I have one or two analyses which prove the average betterment in practical tests, showing from 10 to 12 per cent. general improvement. This flux seems to leave no impurity untouched, but reduces them all; and the strangest part of it is that experiments show that the reductions are in proportion, that is, not reducing the per cent. of one impurity more than another; thus when you have used this flux you have not changed the nature of your casting, but have made a general betterment, which, in the majority of cases, will not injure the casting for the purpose intended, making gray iron softer, but still holding its wearing power, making malleable iron more malleable, but increasing its tensile strength."

In foundry cupola practice, besides the beneficial action of fluorspar already noted together with the general improvement in quality of the iron produced, the following statement of a recent writer, comparing the use of fluorspar and limestone against limestone flux alone, is of interest:

"Fluorspar undoubtedly assists in eliminating slag. The slag is thin, and the metal is kept hotter; consequently, sharper castings will be the result. In addition to this, the charge in the cupola is brought down more rapidly by the use of fluorspar. As to the contention that limestone is far cheaper than fluorspar, this, of course, goes without saying; but the intention is not to use fluorspar alone as a flux, or as a substitute for limestone, but that the fluorspar should be used in conjunction with the limestone, the usual mixture being 20 pounds per ton of iron melted. . . . All of the fluorine in the fluorspar combines with the silicon to form fluoride of silicon, which is a volatile compound and goes out of the stack. This relieves the slag of that amount of silica,

and consequently reduces the refractory nature of the slag. The balance of the calcium fluoride (fluorspar) is then left behind as oxide of calcium, or quick lime, and this behaves exactly as an equivalent amount of limestone would, but as the limestone formed by the decomposition of the fluorspar, is pretty well broken up and distributed through the charge in a very fine state, it forms an exceedingly accurate flux. One reason why less fluorspar is necessary for fluxing a given weight of silica, is the fact that part of the silica is driven out of the chimney, and part of it is slagged off in the charge. In this way, every ounce of fluorspar is used for fluxing, while in the case of the limestone all of the carbon dioxide gas contained in the limestone is driven out of the cupola without assisting the fluxing in any way.”*

In calculating the fluorspar necessary to flux the ashes of coke, in a cupola, the following method may be used:†

“As an example, the following analysis of coke is assumed:

“Analysis of coke:

Fe_2O_3	Al_2O_3	CaO	MgO	SiO_2	S
0.28	4.4	0.2	0.1	4.8	1.0

“Calculation for the silica (SiO_2) fluxed by bases contained in the ash, 4.8 parts contained:

Molecular Weight Basis.					
4 Fe_2O_3 + 3 SiO_2	=640	: 180	: :	0.28	: x = 0.07
4 Al_2O_3 + 3 SiO_2	=411	: 180	: :	4.4	: x = 1.92
4 CaO + SiO_2	=224	: 60	: :	0.2	: x = 0.05
4 MgO + SiO_2	=160	: 60	: :	0.1	: x = 0.03
					2.07

Silica minus 2.07 parts leaves 2.73 to be fluxed by CaF_2 .

“The following analysis is assumed for the fluorspar:

CaF_2	MgO	SiO_2	CO_2	Fe_2O_3	Al_2O_3
88.94	2.08	5.17	2.29	0.83	0.69

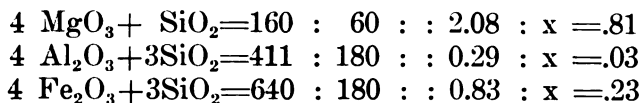
“First Reaction:

$2(\text{CaF}_2) + \text{SiO}_2 = 2(\text{CaO}) + \text{SiF}_4$ is the first reaction that takes place. The fluoride of silicon is volatilized and the lime (CaO) formed is left to combine with remaining silica.

* Iron Age, Oct. 4th, 1906.

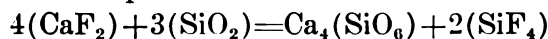
† Blunt, L. G., Calculation for Fluorspar Slag, The Foundry, Vol. 27, No. 4, 1906, p. 196.

“Calculation for the available calcium fluoride in the fluorspar:



1.07

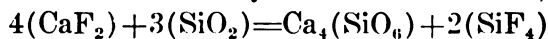
“Hence 1.07 part of silica is fluxed by foreign bases in the fluorspar. $5.17 - 1.07 = 4.10$ SiO_2 remains in the foreign matter of the fluorspar to be fluxed.



or

$$312 : 192 :: x : 4.1 = 6.66$$

“Hence 6.66 parts of CaF_2 are needed to flux the remaining 4.1 parts of silica in the fluorspar. $88.94 - 6.66 = 82.28$, which are the available parts of calcium fluoride in one hundred parts of fluorspar. There are 2.73 parts of silica in the ash of the coke to be fluxed by the calcium fluoride, hence,



or

$$312 : 192 :: x : 2.73 = 4.26$$

“Therefore 4.26 parts of calcium fluoride are necessary to flux 2.73 parts of silica in the coke.

“Since there are 82.28 lbs. available CaF_2 in one hundred pounds of fluorspar; then $82.28 : 100 :: 4.26 : x = 5.18$ pounds; or 5.18 lbs. of fluorspar are necessary to flux one hundred pounds of coke.

“The amount needed to flux the sulphur and the sand on the iron, may be gone through in a similar manner.

“It is very well for one to be cognizant of these reactions and calculations, but the writer does not deem it feasible to use such an elaborate scheme in practice.”

A teaspoonful of ground fluorspar placed dry in the bottom of the hand ladle before tapping will cleanse the metal of all impurities. A tablespoonful in a small bull ladle is sufficient for the same purpose. It glazes the lining of the ladles and keeps them clean as well as removing all impurities.

When used in the ladles alone 1 to 2 pounds are said to be sufficient .

Chilled car wheels cast from foundry pig are greatly benefited when fluorspar is used in fluxing the iron from which they are made, it producing a low silicon iron, and it, it is thought, reduces the quantity of air or sand holes by excluding the hydrogen and oxygen gases contained.

Pure Iron.—Fluorspar has the quality of extracting exceedingly small percentages of phosphorus and sulphur by carrying them into comparatively acid slags for the treatment of very pure qualities of iron. An example is to be noted in Swedish charcoal iron, in which these effects are produced by it.

Aluminum.—The Pittsburg Reduction Co. is the sole producer of aluminum in America. It is known that they have used to some extent American fluorspar in its production, though little is known concerning its technology since they do not give any information on the subject. The Pennsylvania Salt Co., an allied company, is the sole importer of cryolite. Being the American agent for Geo. G. Blackwell & Sons, it also imports fluorspar. Their importation of cryolite has materially lessened in the past two years. This would rather indicate the substitution in part at least of fluorspar as a part of the necessary bath of fused fluorides, in connection with the reduction of bauxite. The manufacture of aluminum in the United States for some years has been nearly, or entirely, by the Hall process. The process was thus described by Packard:*

“The process consists in providing a bath of fused fluorides to which alumina is added, and then reducing this alumina by the current from a dynamo. The bath is contained in carbon-lined iron pots or crucibles, which form the cathodes, while the anodes are large carbon cylinders which are made to dip into the baths. The specific gravity of aluminum being greater than that of the bath employed, the metal sinks to the bottom of the pots, and can be tapped off. To make alloys, the required metal (e. g., copper) may be in-

* The production of Aluminum in 1894, 16th Ann. Rept., U. S. Geol. Survey, Pt. III, p. 540.

troduced into the pot containing the bath and alumina, and, becoming melted, forms a cathode with which the aluminum, as it is reduced from the alumina, unites to form the alloy."

Manganese.—Most of the manganese output is used in iron-manganese alloys which have already received attention. Regarding the production of metallic manganese, Foehr says:

"It has long been known that fluoride of manganese, as well as a mixture of a manganese combination with fluorspar, can be reduced comparatively easily to metallic manganese by means of sodium. This reaction served Brunner in his successful attempts, the first ever made, to produce metallic manganese in large quantities. The modern application of this method to the blast furnace substitutes carbon for sodium."

Gold.—Some assayers in Colorado* add fluorspar to the flux for Cripple Creek ores. They state they obtain higher results in that way. Fluorspar is a powerful flux, and its addition to the assay charge may possibly lead to better results because of the production of a better slag. The same article states that the smelters should pay for the fluorspar as "available lime."

Copper.—In addition to what Foehr has written concerning the use of fluorspar in copper and lead metallurgy, which is now presented, the matter under the caption of Fluorine in Lead and Copper Blast Furnace Slags, beyond, is of interest. Foehr says:

"Fluorspar was formerly the most important flux for smelting copper ores in the German stack, as well as in the English reverberatory furnace. The Mansfield copper slate, for instance, was fluxed with up to 10 per cent. of fluorspar, the cost of this being about 8 per cent. of the total smelting cost. The effect of this flux depended essentially on the volatilization of fluorsilicon, whereby the strongly acid slag was reduced in silica. The introduction of improved and heated blasts in the Mansfield works, has almost confined the use of fluorspar to the blowing in of furnaces. Five per

* Eng. & Min. Jl., Vol. LXXX, 1905, p. 793.

cent. of fluorspar is commonly added at the start, but the quantity decreases gradually until after from two to five weeks no fluorspar is used. In the English reverberatory furnace process formerly the ores were fluxed with as much as 10 per cent. of fluorspar, but nowadays this is done only with ores rich in arsenic. Fluoride of calcium with arsenides of metals gives volatile fluoride of arsenic, which, with a reducing flame, easily escapes. The risk of loss involved in the volatile fluoride of copper necessitates the pressure of an excess of carbon whenever fluorspar is employed in the metallurgy of copper.

“While fluorspar is at present of small value in the treatment of copper ores containing sulphur, its property of giving very fluid combinations with gypsum and barytes may prove an important means for working poor oxides and silicious ores, as well as charges containing azurite, malachite, cuprite, atacamite and earthy red oxide of copper, by reducing the smaller part of the sulphate and forming a matte very rich in copper, and by forcing its larger part together with the fluoride of calcium into the slag which thereby becomes thin and very fluid. Equal quantities of fluorspar with gypsum or barite produce the most fluid slag. A significant point particularly with poor ores high in silica is that this slag is poor in copper, a fact on which was based the former Freiberg practice of resmelting copper slag, together with pyrites and fluorspar, thus obtaining copper matte and poor slag, the intention probably being to enrich the matte in copper and impoverish it in iron.

“Fluxing copper ores containing nickel with fluorspar is very favorable for the collection of the nickel in the matte, and has been in use in Reichelsdorf, Grunthal, and Mansfield works. The chemical process is entirely obscure and is worthy of study in the laboratory. Possibly nickel arsenide is decomposed into volatile fluoride of arsenic and nickel, which latter goes into the matte. Fluorspar is an almost indispensable flux for making tough copper, and generally, whenever silicon, which makes copper highly brittle, has to be removed. As a means of producing a matte poor in iron in the reverberatory furnace, a mixture of fluorspar, barite

and quartz is more energetic and rapid than an addition of only the last two named, the proportion of the fluorspar and barite being for this purpose as between 1 and 3, whilst the quantity of quartz depends upon how much iron the roasted matte contains. Too much fluorspar gives a matte rich in iron. For refining and resmelting copper, fluorspar finds a constantly increasing use. Mixed with some soda it is most excellent in resmelting copper ingots and for removing from the metal both small quantities of arsenic and silicon. The process is kept a secret; the refining slag is, however, reported to be resmelted with gypsum and glauber salts and fluorspar."—(Foehr.)

"Lead and Silver.—The introduction of the Pilz and Raschette furnaces has made lead and silver smelting without fluorspar a possibility. It is too expensive for this purpose, except for particularly refractory ores.

"For resmelting lead slags, also, a small amount of fluorspar flux is serviceable. It is used, too, for smelting on the Spanish slag hearth.

"As in improved lead works, the ores to be smelted are almost invariably first roasted; the fluorspar is added at the roasting. The quantity varies from 3 to 5 per cent., according to the percentage of quartz in the ores. One per cent. of fluorspar, if ground as finely as possible, causes a noticeable economy in fuel. As this flux lowers the temperature in a roasting furnace and shortens the roasting process, the yield of metal must also be favorably affected.

"In refining, also, fluorspar is very advantageous, especially when sprinkled on the bath in a fine powder. The litharge is thereby made thinner and retains fewer metallic grains mechanically. The same effect is reached by adding a small quantity of soda, or a mixture of soda and fluorspar.

"It has proved most excellent for fluxing ores containing barytes and zinc. Possibly the temperature of the slag formation is reduced, thus diminishing the quantity of metal lost through volatilization. This is of greater importance in the reverberatory than in the stack furnace, so that the use of fluorspar might occasion a special modification of the

English reverberatory furnace, a Derby process, with a flux of about 7 per cent. fluorspar.”—(Foehr.)

Fluorine in Lead and Copper Blast Furnace Slags.—The article by L. S. Austin* upon this subject is of much interest, and is quoted in full:

“The occurrence of fluorine in lead (or copper) blast-furnace slags is a subject that seems to be ignored by most of the authorities on smelting, but it is well worthy of attention. In relation to this occurrence, I can furnish the following information:

“Smelting plants treating Mexican ores have to take into consideration the quantities of fluorspar present in them. For example (and referring to ores of the northern part of Mexico) the Nina Vera contains at times as much as 15 to 17 per cent. of CaO , combined with fluorine; ore from the Veta Grande may carry as much as 10 per cent.

“Inasmuch as the presence of fluorspar is an advantage in smelting an ore, it must be taken account of, since the fluorine needs CaO to satisfy its needs, and this lime is not available for any other purpose (as, for example, to assist in fluxing the silica.) Hence, if we are intending to run a type slag (of the composition 34 per cent. SiO_2 , 33 per cent. FeO , and 23 per cent. CaO) in a charge containing 2 per cent. fluorine, the CaO would have to be raised to 27 per cent. to satisfy the fluorine present.

“I have by me two examples of slag, one containing 1 per cent. fluorine, and the other 3 per cent. Now, another difficulty presents itself in running these slags. The silica (as ordinarily determined) is bound to be reported low, since the HF will carry some of it off when evaporating the solution to dryness to render silica insoluble. This increases the trouble to the metallurgist; since, if unaware of the presence of fluorine, he would imagine he had a sufficiency of lime, when, in fact, he should add still more to his charge.

“Inattention to this requirement in fluxing the charge has resulted not only in giving a slag high in silver and lead, but even in freezing up the furnace, to the discomfiture of

* Eng. & Min. Jl., Vol. LXXX, No. 19, 1905, p. 865.

the metallurgist, who did not know where was the difficulty nor what would be the proper remedy for the trouble.

"In actual operation, the plan has been to consider the CaO , which will remain on digesting the ore with acetic acid, as being in combination with fluorine, and, by keeping a record of all such lime in the charge, it is possible to estimate the amount of it so combined in the slag. Aside from this, no further determinations are considered essential to the daily blast-furnace operations.

"The analysis of the slags for fluorine by the classified methods is quite tedious; nevertheless, such work has been performed, and this resulted in finding it present in them."

Both Kneeland* and Austin† agree that lime in the shape of fluorspar requires CaO to satisfy its needs; and aside from imparting an increased fluidity to the slag, the fluoride of lime therein (when its presence is known and allowed for) is inert, and does not change its nature upon melting in the furnace.

Kneeland expressing clearly and in another manner, in the second paragraph below, what Austin sought to bring out in his third paragraph, states further:

"It has been asserted that the increased fusibility of the charge resulting from the presence of fluorspar (where lead smelting is being practiced,) causes an imperfect reduction, as the ore melts too quickly to give time for proper reduction to take place. Regarding this statement, although it seems plausible, yet I was unable to notice the difference in the reduction, whether we made slags with 1 per cent. of fluorine, or whether the amount present was 3 per cent. if the same amount of coke was used in the charge. As I have had no experience with slags containing more than 3 per cent. of fluorine, I can not say what would be the result where this percentage greatly increased. * * *

"Again, I believe that the trouble to the metallurgist (where there is fluoride of lime to be contended with, the presence of which is not suspected) is that in slag analysis, run in the ordinary way, the total amount of lime present is reported; a portion of this lime being inert or unavailable, leads the metallurgist to believe that there is more

*Eng. & Min. J1, Vol. LXXX, 1905, No. 22, p. 1080. †—Same, No. 26, p. 1222.

basic material in the slag than is actually the case. I believe there is a more serious result from the presence of small amounts of fluorine in the slag, than the slight error in determining the silica due to its evaporation as tetrafluoride of silicon."

In the chapter on Analytical Methods will be found Mr. Kneeland's method of determining fluorine in ore or slag.

Tin.—"The slags of tin ores are generally very acid in the stack, as well as in the reverberatory furnace. As it is particularly desirable here to reduce the quantity of the slag as much as possible, fluorspar, which has this property and in addition makes the slag fluid, has long ago found use, especially in English tin works, where it sometimes forms 5 per cent. of the charge. Commonly, burnt limestone and fluorspar are mixed, although it seems far preferable to employ soda than lime. The fluorspar fluxing must not be too liberal; otherwise the furnace walls are attacked and tin seems to go into the slag."—(Foehr.)

Nickel.—"When the price is not too high, fluorspar is an advantageous means of fluxing garnierite (nickel and magnesia silicate), but still more important in the concentration of speiss (a residue of matte containing the nickel and other arsenides, remaining from separation of cobalt in reducing cobalt-nickel ores)."—(Foehr.)

Zinc.—Fluorspar with zinc ore seems very undesirable, as it attacks the distilling vessels. On the other hand, in order to overcome this obstacle, a material composed of pure quartz sand with about 3 per cent. of fluorspar and some soda, has been tentatively used for tubes and muffles, which, though apt to frit on the surface in annealing, becomes, on the escape of fluorspar, far more dense than can otherwise be obtained. The ordinary zinc-distilling vessels are said to be extraordinarily improved by a glaze baking consisting of sulphate of zinc and fluorspar in equal quantities, in regard to product, as well as durability of muffles. In refining pig zinc, the remelting is sometimes facilitated by adding a mixture of glauber salt, rock salt and fluorspar.

Zinc smelters consider fluorspar objectionable, since: (1) It is decomposed in the roasting furnace (wherein the temperature is only about 1,000 degrees C. as the maximum) with the evolution of fluorine vapors, which are destructive to the lead chambers if the roast gas be employed in the manufacture of sulphuric acid.* Mere heating does not affect the decomposition, which is due to the action of the sulphuric gases (evolved upon roasting zinc) upon the fluorspar, at or above 130 degrees, hydrofluoric acid being formed. (2) It leads to highly fusible slags. (3) Its destructive action upon the ordinary retort. This, the most objectionable of the three, it is now possible to overcome through the invention of Queneau† of composite zinc retorts capable of construction with basic linings at a low cost. For such linings chromite or similar basic substances may be employed.

In the Production of Alundum.—Fluorspar is used to some extent by the manufacturers of alundum, a patented artificial corundum, used in making emery wheels and producing wheels of better quality than those made of the natural product.

Alundum is made from bauxite, which receives preliminary heating to drive off combined water and is then melted directly in electric furnaces of especial design. The temperature at which the furnace charge melts in a homogeneous mass is estimated at 6,000 to 7,000 degrees F. The solid massive alundum while resembling the purest natural corundum in chemical composition (Al_2O_3) is considerably harder than the natural product, the former having a hardness in excess of $9\frac{1}{2}$, the latter only 9. The greater hardness of alundum is attributed partly to the perfectly fluid condition in which the mass is melted.‡ It is to be inferred that it assists both in reducing the melting temperature and in bringing about the perfectly fluid condition.

In the Manufacture of Glass.

Common and Plate Glass.—As already pointed out, the use of fluorspar in the manufacture of glass shows a notable increase; over $2\frac{1}{2}$ per cent. of the total American consump-

*W. R. Ingalls, *Metallurgy of Zinc*, p. 84. p. 218.

†Queneau, A. L., *Composite Metallurgical Vessels*, *Eng. & Min. J.*, Vol. LXXXII, No. 15, 1906, pp. 677-679.

‡Alundum and Its Manufacture, *Iron Age*, November 8, 1906.

tion going now to the glass makers. Little concerning its technology connected with the manufacture of common and plate glass can be given at present. In this industry it is used as a flux to render certain constituents more fusible.

The action of fluorspar in the melting pot is said to have caused a perfection to be reached in American glass manufacture that a few years ago would have been considered impossible. American plate and cut glass is not only on a par with the French, but has a finish and brilliancy that no other glass can equal without the use of fluorspar in its production. One of the benefits attributed to its use in the making of plate glass is that of its imparting limpidity, thereby permitting it the more readily to be rolled. For plate glass the best grade of ground fluorite should be used, while the second grade ground is suitable for common glass, although higher percentages of silica are permissible in glass manufacture than in acid manufacture; in fact up to 2 per cent. is not objected to by the consumers.

Opaque and Opalescent Glass.—In general practice cryolite, phosphate of lime or fluorspar and feldspar have been used in the production of opaque and opalescent glass. When such glass is made with cryolite or fluorspar it contains fluorine, while that made with phosphate of lime contains phosphoric acid. The use of cryolite in the manufacture of this glass is on the decline, owing to the high per cent. of fluorine it leaves in the glass and which attacks the vessels in which the melt is made. The phosphate glass contains a high per cent. of phosphoric acid, also very undesirable. That made with fluorspar and feldspar leaves only half as much fluorine in the glass as the cryolite, and is considered the most suitable of the three processes. Consequently fluorspar-feldspar glass has almost completely superseded that of the other two processes. Second grade ground fluorspar is suitable for this purpose, ground as fine as possible. Thus finely ground, mixed with the remaining ingredients, and properly heated, it brings about the even distribution of particles requisite to produce opacity, being especially well adapted for this by its quality of producing very homogeneous masses. A transparent glass first re-

sults, which upon being reheated and maintained for a time at a temperature near the fusing point, becomes opalescent, frequently showing streaks produced by the hottest parts of the flame in which the glass was heated; some very beautiful effects are thus secured.*

Below are given representative analyses of cryolite, phosphate, and fluorspar-feldspar glass:

Cryolite Glass.		Phosphate Glass.		Fluorspar.	Feldspar Glass
	Per Cent.		Per Cent.		Per Cent.
SiO ₂	59.85	SiO ₂	49.58	SiO ₂	76.11
Al ₂ O ₃	10.71	B ₂ O ₃	9.15	Al ₂ O ₃	3.04
ZnO	8.13	CaO	15.77	CaO	3.73
Na ₂ O	14.07	Na ₂ O	12.48	Na ₂ O	9.21
As ₂ O ₃	1.06	K ₂ O	1.44	K ₂ O	4.26
F	6.18	P ₂ O ₅	11.58	F	3.65

Enamels, Glazes and Fireproof Ware.

Fluorspar is one of the enamel fluxes. It is used in combination, generally, with a refractory substance, as when used alone it reduces the refractory character of the enamel. It is used to replace a part of the carbonate of soda and boracic acid sometimes used. It may be used as a flux in preparing the overglaze or colored enamels of porcelain ware, etc. Since the coloring matter of fluorspar is not due to metallic oxides, but to hydrocarbons readily volatilized, colored fluorspar may be as readily used as the colorless, the latter likewise containing hydrocarbons. For hollow and sanitary ware, No. 2 ground fluorspar is suitable. Lump or gravel fluorspar is sometimes used, it being ground directly with the other enamel ingredients. For the finest enamels, No. 1 ground fluorspar is preferable.

Fluorspar is used in small quantities in making fireproof ware, presumably in fluxing the materials more thoroughly, making them more homogenous and dense, the fluorspar volatilizing on heating sufficiently in the kiln. In this connection, it is used for fireproofing and glazing clay crucibles.

*Mineral Resources, U. S. Geol. Survey, 1886, Fluorspar, p. 602.

A little more than 2 per cent. of the total fluorspar consumption goes into enamels. Of this a little more than half is purchased in the ground form, the remainder largely as lump, some gravel. About 50 per cent. of that used for enameling is employed for enameling bath tubs and sanitary plumbing; 40 per cent. in making enamel ware, such as cooking utensils, etc., including also a very small per cent. used in enamels for watch and clock dials, etc.; and 10 per cent. for glazing fancy tile and brick.

Apochromatic Lenses.

An apochromatic lens is one that shows objects, viewed or magnified through it, more nearly free from color rings than is obtainable with any other kind of lens. For this purpose certain transparent minerals crystalizing in the isometric system (cubes, octahedrons, etc.) come nearest fulfilling the required conditions, because they do not show objects viewed through them double (double refractions). The diamond is suitable when found completely transparent, but owing to its high refractive power and reflection from two faces, rarely occurs in this condition, not to mention its prohibitive high cost and difficulty of grinding.

Fluorspar has low refractive and dispersive powers and hence is especially adapted to the production of such lenses, as was pointed out by Abbe. It is much sought after by European optical makers where perfect lenses are necessary for the highest class of such instruments as spectrosopes, etc. Such lenses show very low differences because of refraction. For the three hydrogen lines H, H, and H, the differences in refractive indices are $n - n = 0.00455$ and $n - n = 0.00255$.* It is of special value for certain work in ultra-violet light.

Fluorite pellucid (water clear) enough for this purpose is, however, extremely rare. It is to be found in simple crystals of fluorspar groups which are either colorless or very light yellow, green, blue, etc. As the crystal faces are usually dull or have a satin luster, it is necessary to cut off (truncate) the corners of the cubes along cleavage planes,

* Dana, *New System of Mineralogy*, 1901, p. 1034.

to determine whether it contains any sufficiently clear and flawless. The clearest portion usually occurs in the center of the triangular face exposed by truncation. A peculiar property of fluorite of this quality is its conchoidal (irregularly curved) fractures and less facile cleavage. Twinned crystals usually show flaws due to striae along twinning planes, hence do not contain optical fluorite. Pieces as small as one-quarter inch across may serve for lenses, though of course larger ones are more valuable. Prices range according to size and quality of pieces.

Fluorspar for Ornamental Purposes.

Fluorspar crystallizes in the isometric system, commonly in cubes. It cleaves perfectly into octahedrons and secondaries. Being only about one-half as hard as most gems and somewhat brittle, it is not suitable for continuous wear though it is sometimes cut as a gem. It is phosphorescent when slightly heated, while the variety chlorophane, according to Kunz, may be distinguished by its being fluorescent (emitting light only as long as an exciting agent is applied), both triboluminescent (emitting light by slight application of friction) and thermoluminescent (emitting light by slight application of heat). This forms a new kind of gem, e. g., a fluorescent gemstone. Chlorophane has been found at Amelia, Va.

Fluorite occurs in white, yellow, green, violet, sky and amethystine blue, brown, wine yellow, rose red, crimson and pink, also pellucid. Most of the crystalline faces of American fluorspar are dull, differing in this from the English. Cutting, however, materially heightens the colors, so that very beautiful cleavages are obtained, the writer having many such in his collection. Such are, however, still more beautiful by transmitted light. Some excellent gem effects may be obtained by encasing cut cleavages in small glass globes, placing a minute incandescent electric light beneath the cleavage. Fluorite is occasionally found shaped into ornaments by the hand of prehistoric man. Kunz has obtained specimens of such for his collection, from the mounds of Southern Illinois. The less perfect cleavage might be used for cheap jewelry settings. Fluorite is also known as chlorophane,

pyro-emerald, fluorspar, Derbyshire spar and Cabra stone. Finely colored specimens are also known, according to color, as false ruby, false topaz, false emerald, false amethyst, etc.

The massive, coarse grained and fine grained varieties are made into paper weights, trinkets, vases, etc., in Derbyshire, England. The fluorspar is first shaped by the lathe and a fine steel tool, and is finished off with pumice and emery. The blue color may be changed to amethystine blue by slightly heating, though excessive heating will completely bleach it. The Tiffany collection at the St. Louis Exposition contained a very handsome blue fluorspar vase.

Fluorspar has been rarely used in America for ornamental purposes, but since there is an abundance available for such purposes there is no reason why it should not be.

Carbon Electrodes for Flaming Arc Lamps.

The production of incandescent mantles of the Welsbach type led to the application of additional energies to produce an incandescent arc for electric lighting. Fluorspar not only seems best in assisting to produce this effect, but its use in proper quantity, as is indicated by the investigations of Prof. Dr. Herman Wedding, produces a light more economical than that of the ordinary arc light.

The ordinary electric arc lamp depends on the positive electrode for luminosity. In the flaming arc lamp, an incandescent arc is produced by the presence of suitable mineral matter in addition to the usual vaporization of carbon. It has been demonstrated that the presence of mineral matter not only augments the luminosity, but also diminishes by one half the current consumption for a given luminosity. Electrodes for this purpose are composed of carbon and some salt of calcium, usually fluorspar. Prof. Wedding in his studies on the influence of this substance on the consumption of energy in the lamp, has found that the most favorable conditions are found with .15 per cent. of fluorspar. Electrodes of this composition are found to consume but 0.15 watts per candle, as compared with 0.5 watts for the ordinary arc.*

* Berthier, A., Some New Modes of Lighting, Smithsonian Ann. Rept. for 1904, p. 267.

CHAPTER VII.

METHODS OF ANALYSIS OF FLOURINE COMPOUNDS.

Qualitative Determination.

The methods given by Brush-Penfield,* together with additional notes on the potassium bisulphate method by Richards, are the best available, and are here given.

The etching of glass and the formation of volatile compounds with silicon, furnish the best methods for the detection of fluorine.

1. Etching of Glass.—This test is applicable only to compounds, other than silicates, which are decomposed by sulphuric acid. Prepare a piece of glass by melting a little paraffin upon it, moving it until a thin, even coating is formed, and then allowing it to become cold. By means of any pointed instrument, which must not, of course, be hard enough to scratch the glass, draw lines through the paraffin, then apply the finely powdered mineral and a few drops of concentrated sulphuric acid, spreading the mixture about by means of a slip or roll of paper where the glass has been exposed, and allow the etching to go on for five minutes longer. Afterward, wash off the acid, warm the glass, remove the paraffin by rubbing with paper, and examine carefully to see if any etching has been produced.

The reactions in the case of fluorite may be expressed as follows: $\text{CaF}_2 + \text{H}_2\text{SO}_4 = \text{CaSO}_4 + 2\text{HF}$; and SiO_2 (from the glass) $+ 4\text{HF} = \text{SiF}_4 + 2\text{H}_2\text{O}$. It is owing to the affinity of fluorine for silicon that the glass is etched.

2. Test With Potassium Bisulphate.—This test is often more convenient than the foregoing, but can be applied only to compounds which are decomposed by sulphuric acid. Mix the powdered mineral with 3 or 4 volumes of potassium bisulphate, transfer to a bulb tube, being careful that the mixture does not fill the bulb more than one quarter full, and heat over a small Bunsen-burner flame. The liberated hydrofluoric acid etches the glass, and this etching is usually

* Manual of Determinative Mineralogy, 15th Ed. 1902, pp. 75-77.

seen very distinctly as a clouding of the sides of the bulb and lower part of the tube. The silicon fluoride and water formed by the reaction yield hydrofluosilicic acid and a deposit of silica. The reaction is: $3\text{SiF}_4 + 2\text{H}_2\text{O} = 2\text{H}_2\text{SiF}_6 + \text{SiO}_2$. The deposit of silica is the most conspicuous feature of the reaction, and constitutes a proof of the presence of fluorine, for without fluorine it could not have formed.

If heated, the silica may be driven up the tube, because SiO_2 , $2\text{H}_2\text{SiF}_6$ form the vapors $2\text{H}_2\text{O}$, 3SiF_4 , but the silica deposits again where the glass is cold enough to condense the water. If the upper portion of the tube containing the deposit of silica is cut off from the bulb and dipped gently into water, so as not to carry off the silica mechanically, the hydrofluosilicic acid will be removed, and when the tube is dried the silica will no longer be volatile. When the reaction is not very decided, the washing and testing of the silica should never be omitted, for often a little sulphuric acid, driven off from the potassium bisulphate, condenses as a white deposit, which might be mistaken for silica.

The following notes relating further to the potassium bisulphate test, are of interest:

In the Journal of the American Chemical Society, J. W. Richards says, of tests of fluorine, that while fusion with potassium bisulphate decomposes any fluoride, the test of the vapors with Brazil wood is not reliable. He finds it better to make the fusion in a rather large closed tube, of say 5 to 8 mm. diameter, heating regularly with the tube almost horizontal. The silica ring deposits just above the assay, and the odor of the gas is often quite plain. Cool the tube, nick it below the silica ring, break, and hold the upper end vertically under, and close to the nose. At this instant the odor of hydrofluoric acid will be perceived with certainty, if any has been driven off, and by a little experience the odor can be distinguished with as much certainty as the smell of ammonia. A still more conclusive proof consists in letting water run slowly over the silica ring. If it is merely a sublimate of a volatile salt, it will be dissolved and disappear; if it is the true silica ring, it will become gelatinous, seen under the lens, and on carefully drying the tube the white ring is again strongly in evidence.*

* Engineering and Mining Journal, Vol. LXXI, No. 23, 1901, p. 727.

3. Test With Sodium Metaphosphate.—This test will often be found convenient, since it can be applied to minerals which are not decomposed by sulphuric acid. If the finely powdered mineral is mixed with from 4 to 6 parts of sodium metaphosphate, transferred to a bulb tube (which should not be more than one quarter full), and heated very hot, hydrofluoric acid will be given off, which etches the glass, and deposits a ring of silica exactly as described in No. 2. This test is excellent for silicates when the proportion of fluorine is not too small (less than 5 per cent.), but when very small quantities are to be detected, the method given in No. 4 is preferable.

Sodium metaphosphate may be prepared by heating phosphorus salt in a platinum dish until ammonia and water are expelled; or a sufficient quantity for an experiment may be made quickly by fusing beads of phosphorus salt on platinum wire, and crushing them in a diamond mortar. In the case of fluor spar their actions are:

$\text{CaF}_2 + \text{NaPO}_3 + \text{H}_2\text{O} = \text{CaNaPO}_4 + 2\text{HF}$. It is evident that water or hydroxyl must be present in order to form HF, and this may come either from hydroxyl in the mineral or from a trace of water that was not wholly driven out from the sodium metaphosphate.

4. Precipitation as Calcium Fluoride.—This test is especially applicable for detecting small quantities of fluorine in silicates. The mineral is first fused with sodium carbonate, exactly as described under silicates. The fusion is then pulverized, treated in a test tube with 5 cc. of boiling water filtered and washed, by which means sodium fluoride is obtained in solution. The filtrate is acidified with hydrochloric acid, boiled for a short time to expel carbon dioxide, a little calcium chloride added (some calcite dissolved in hydrochloric acid will answer), and then ammonia in excess. The precipitate will contain calcium fluoride, but a precipitate is not a proof that fluorine is present, for other compounds may be thrown down at this point. The precipitate must be collected in a filter-paper, washed well with water, and ignited in a crucible until the paper is completely destroyed, when the residue is tested according to No. 2. It is not safe to test according to No. 1, for sometimes considerable silica is precipitated with the calcium fluoride, and in that case the hydro-

fluoric acid will derive silica from the precipitate instead of etching the glass.

5. Acid Water in a Closed Tube.—Most minerals containing fluorine and hydroxyl yield acid water in the closed tube, which reddens blue litmus-paper, and when the reaction is strong the glass is distinctly etched. Unless the glass is etched, however, a proof of the presence of fluorine must be obtained by testing according to some of the foregoing methods. In cases where fluorine is isomorphous with hydroxyl, hydrofluoric acid will sometimes be given off instead of water. The acid then etches the glass, forms a deposit of silica, and gives a strong pungent smell at the end of the tube. From Brazilian topaz, for example, which on analysis yields 2.5 per cent. of water, the hydrogen is mostly expelled as hydrofluoric acid, and there is scarcely any indication of water, but, if freshly ignited lime or magnesia is mixed with the mineral in the closed tube, the fluorine will be retained and water driven off.

Quantitative Determination.

The following methods for "Direct Determination of Fluorine;" for "Indirect determination of Fluorine;" and for "Complete Analysis of Fluorspar," are presented by a writer in the *Chemical Engineer* (Vol. III, No. 2, 1905) as sufficiently quick and accurate for ordinary purposes (as in the case of commercial fluorspar). The "Direct Determination" is credited to Penfield's "Volumetric Method," *Am. Chem. J.*, 1, 27.

DIRECT DETERMINATION OF FLUORSPAR.

Solutions and Reagents.

One-fifth Normal Caustic Soda Solution, prepared and standardized in the usual manner.

1 cc of this solution = 0.0284 gram CaF_2 .
= 0.0114 gram F.

Alcoholic Potassium Chloride Solution, prepared by dissolving 30 grams of potassium chloride in 100 cc. of water, and adding 100 cc. of alcohol. Twenty cc. of the solution are used for each determination.

Lacmoid Indicator, prepared by dissolving 0.2 grams of lacmoid (resorcin blue) in 100 cc. of alcohol. This indicator is red with acids and blue with alkalis.

Powdered Silica.—Ignited powdered quartz or precipitated silica will either of them answer the purpose, provided they are free from fluorine.

Sulphuric Acid.—This must be concentrated. It is best to heat it in a well annealed flask until it fumes strongly and then cool, stoppering the flask with a perforated cork carrying a 6-inch piece of capillary tube until the acid is cold, and then with a solid rubber stopper.

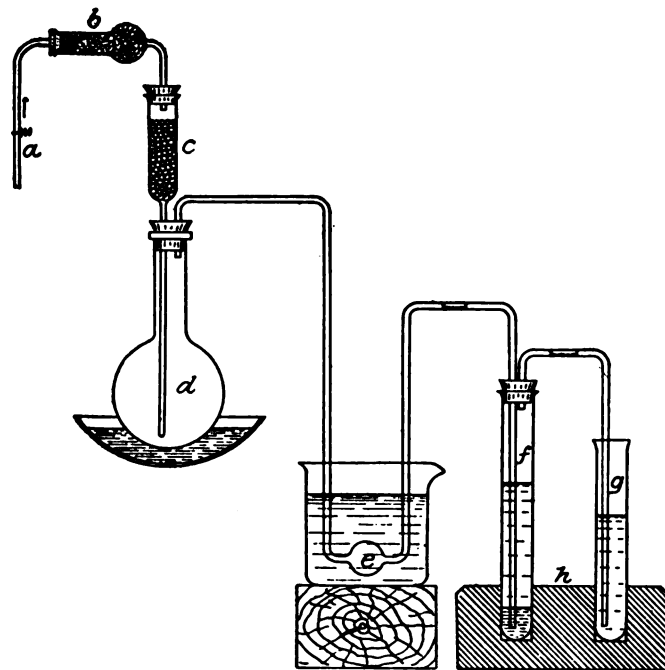


Fig. 1.

APPARATUS FOR DETERMINING FLUORSPAR. (The Chemical Engineer.)

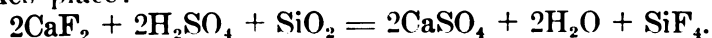
The apparatus is shown above and consists of a well annealed 250 cc. flask, d, closed by a two-hole rubber stopper. Through one of these holes, passes a funnel, c, which can be easily made by joining a piece of glass tubing on to a calcium chloride tube to form a long enough stem to reach nearly to the bottom of the flask. The funnel is filled with dry glass beads, and is closed by a stopper, in the single hole of which

is inserted a calcium chloride tube filled with dry granular soda-lime. The rubber tube, a, connects the apparatus with the source of a current of air, which later can be shut off by the Hoffmann clamp as shown. In the second hole of the flask stopper, a condenser tube, e, bent as shown, is inserted. This is made by blowing a bulb in a piece of glass tubing (6 mm. in diameter), and is kept cool by immersion in a beaker of cold water. The test tube, f, is connected to e by a rubber joint, as shown, and is provided with inlet and outlet tubes, the latter being connected with the inlet tube of another test tube, g. The test tube, f, is 8 inches high, while g is only 6 inches. Both tubes are held upright by a small block of wood, h, bored with holes to fit the tubes.

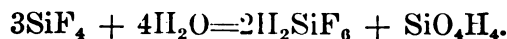
Determination.—Have the flask and the condenser tube, e, and the entrance tube to the test tube, f, thoroughly dry. Pour about $\frac{1}{2}$ inch of mercury into the test tube, f, and on top of this 25 cc. of the potassium chloride solution. Half fill the test tube, g, also with this solution.

Now weigh into an agate mortar 0.2 to 0.5 gram of the finely powdered sample, place the mortar on a piece of black-glazed paper and carefully mix, by gently rubbing with the pestle, the sample of fluorspar with ten times its weight of powdered silica. After mixing, transfer to the flask, cork the latter and connect up the apparatus as shown. Pour 25 cc. of concentrated sulphuric acid through the funnel, c, (and the glass beads) into the flask, d. As soon as the acid is poured into the funnel, close the latter with the stopper and guard tube, b. Place the flask in a bath of paraffin and heat to about 160°C. for one or two hours. A slow current of air is passed through the apparatus during this time. The test tube, f, is then disconnected from the condenser tube, e, and its contents, together with that of g, are rinsed into a beaker. A drop of lacmoid indicator is added to the contents of the beaker, and the mixture titrated with the standard alkali. The percentage of fluorine is then calculated, as usual, from the weight of sample taken and the number of cc. of alkali required.

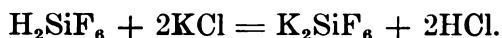
The process depends upon the fact that upon treatment of fluorides with sulphuric acid and silica the following reaction takes place:



Upon coming in contact with water the silicon fluoride is decomposed into hydrofluosilicic and silicic acids:



The hydrofluosilicic acid unites with the potassium chloride, forming potassium silicofluoride (insoluble in 50 per cent. alcohol) and hydrochloric acid:



The hydrochloric acid set free is, of course, titrated and as $3\text{F}_2 = 2\text{HCl}$, 1 cc. N/5 alkali = 0.0114 grams fluorine.

INDIRECT DETERMINATION OF FLUORINE.

The following method, while not so exact as the foregoing one, will, in many instances, give correct results, particularly if the amount of silicate of lime in the fluorspar is small, as is usually the case. The sample should be very finely ground (or until no grit is detected on biting between the teeth). The determination is then detected as follows:

One-half gram of fluorspar is weighed into a small beaker and moistened with water. Five cc. of strong acetic acid are added, and the contents of the beaker boiled nearly to dryness (a bulk of 2 or 3 cc.) The pasty mass is diluted with 10 cc. of acetic acid and 15 cc. of water, boiled for a few minutes, filtered, and the residue washed with hot water. The filter paper and residue are placed in a small platinum dish or a large platinum crucible and ignited until all the paper is consumed. After cooling, 5 cc. of strong sulphuric acid are cautiously added to the residue in the dish and the mixture evaporated to dryness. The dry mass is then dissolved in 50 cc. of water and 10 cc. of hydrochloric acid with the aid of heat, the solution is filtered, and the filtrate heated to boiling. Ammonia is then added until the solution smells faintly of the reagent and the solution is boiled for about a minute. Ten cc. of a 10 per cent. solution of oxalic acid and 250 cc. of water are now added and the lime precipitated with 30 cc. of saturated ammonia oxalate solution and filtered off, washed well and determined volumetrically with standard permanganate. The percentage of lime (CaO) found multiplied by 1.392 gives the percentage of

calcium fluoride (CaF_2), or by 0.6774 gives the percentage of fluorine (F_2).

This method depends on the fact that calcium fluoride is not decomposed by acetic acid while calcium carbonate is dissolved.

COMPLETE ANALYSIS OF FLUORSPAR.

When the silica is present as quartz or silicates undecomposed by hydrofluoric acid, a complete analysis of fluorspar may be made by the following scheme: Weigh 0.5 gram of fluorspar into a small platinum dish or a large platinum crucible, add 10 cc. of strong sulphuric acid, and evaporate to dryness. If a crucible is used, the evaporation may be conducted rapidly in the following manner: Incline the crucible on a tripod over a burner turned low, in such a way that the flame plays only under the upper part. When white fumes cease to come from the crucible or dish, cool and add 10 cc. of strong hydrochloric acid. Cover the solution and digest for 10 minutes on the hot plate, dilute with 50 cc. of hot water, heat until calcium sulphate is all in solution, filter off, wash, ignite and weigh the residue of silica. The iron oxide and alumina, lime and magnesia are determined in the filtrate as in a limestone analysis, and the fluorine is found in a separate sample by one of the methods outlined above.

Where silicates decomposable by hydrofluoric acid are present in the sample, the following method gives fairly accurate determinations of silica and fluorine:

Treat 0.5 gram of fluorspar with acetic acid as directed for the indirect determination of fluorine and filter.

Residue 1.—Ignite over a bunsen burner at a red heat for 15 minutes and weigh. Treat the contents of the crucible with 5 or 6 cc. of hydrofluoric acid, and evaporate to dryness as directed in the preceding scheme and ignite for 15 minutes at a red heat. Cool and weight. Loss in weight= SiO_2 . The residue is then heated with 5 cc. of strong sulphuric acid and evaporated to dryness. The dry mass is dissolved in 10 cc. of strong hydrochloric acid, diluted with 50 cc., filtered and washed. (2)

Residue 2.—Ignite and weigh as silica. Add to silica found above.

Filtrate 2.—Add 5 cc. of bromine water and heat to boiling. Add ammonia in slight but distinct excess, boil, filter and wash. Re-precipitate if much iron and alumina is present and combine filtrates; (3)

Residue 3.—Ignite and weigh as iron and alumina. Add weight to that found in column II.

Filtrate 3.—Heat to boiling and add 20cc. of 10% solution of ammonia oxalate, stir and allow to settle. Filter and wash. (4)

Residue 4.—Dissolve in sulphuric acid and titrate with permanganate. Calculate to both CaO and to F ($=\text{CaO} \times 0.6774$). Add weight of CaO to that found in column II.

Filtrate 4.—May be discarded unless magnesium fluoride may be present, when magnesium is determined as usual, and the fluorine corresponding to this is calculated ($\text{MgO} \times 0.9415 = \text{F}$), and add to the fluorine found above, while the magnesia is added to the weight of that found in column II.

Filtrate 1.—Make alkaline with ammonia, add 10 cc. bromine water and boil. Allow the precipitate to settle, filter and wash. (If much iron and alumina are precipitated, dissolve the precipitate in nitric acid and re-precipitate with ammonia, boil, filter and wash, combining the filtrates); (5)

Residue 5.—Ignite and weigh as iron and alumina. Combine weight with that of Residue 3 in column I.

Filtrate 5.—Heat to boiling and precipitate the lime as oxalate, allow to settle, filter and wash. (6)

Residue 6.—Dissolve in sulphuric acid and titrate with permanganate. Calculate to both CaO and CO_2 ($=\text{CaO} \times 0.7857$). Combine weight with that of Residue 4 in column I.

Filtrate 6.—Evaporate to 150 cc. Make alkaline and precipitate with ammonium phosphate, as usual. Filter, ignite and weigh. (7)

Residue 7.—Calculate to MgO ($\text{Mg}_2\text{P}_2\text{O}_7 \times 0.8824$) and CO_2 ($=\text{MgO} \times 1.09$.)

Commenting upon the foregoing, W. George Waring says:*

"The schemes given in the Chemical Engineer III 65, for the analysis of fluorspar seem to me to require that certain precautions should be observed, due to the fact that it is difficult, if not impossible, to completely decompose fluorspar by heating alone with concentrated sulphuric acid. If, however, the residue insoluble in hot dilute hydrochloric acid be taken up in a very little strong hydrochloric acid and the acid solution be treated with an excess of potassium oxalate, the dissolved calcium fluoride will precipitate as oxalate, and can be determined and deducted from the weight of the residue. In like manner the ammonical precipitate of alumina, etc., from the main hydrochloric solution always contains considerable calcium fluoride, which may be estimated by a like procedure.

"The following example is typical of many actual results showing the need of the foregoing precautions:

Illinois fluorspar, No. 29269:

CaO as carbonate, by acetic acid.....	0.61=1.09	CaCO ₃
SiO ₂ vol. by H.F.	0.40	SiO ₂
Insol. from dilute HCl	12.35	
CaF ₂ found in same	12.17	
Leaving	0.18	insol.
Al ₂ O ₃ etc., by ammonia	2.08	
CaF ₂ found in same,	1.64	
Leaving	0.89	Al ₂ O ₃ , etc.
CaF ₂ in ammoniacal filtrate	84.15	} 97.96 CaF ₂
CaF ₂ in insol.	12.17	
CaF ₂ in ammonia pp	1.64	
MgO		trace
		<hr/> 100.02

KNEELAND'S MODIFICATION OF FRESSENIUS METHOD.

Kneeland, pointing out the inaccuracy of the acetic acid determination of available lime where other indigestible lime combinations besides fluorspar are present, presents the following modification of the old Fresenius method, which while technically accurate is adaptable for use in the ordinary run of smelter laboratories, permitting a number of determinations to be made per day without interfering materially with the other laboratory duties:†

"Fuse 0.5 or 1 gram of the material (according to the supposed amount of fluorine present) in a porcelain crucible

* The Chemical Engineer, Vol. IV, 1906, No. 1.

† A Method of the Determination of Fluorine in an Ore or Slag, Engineering and Mining Journal, Vol. LXXX, 1905, p. 1212.

with 10 times its weight of a mixture of equal parts of carbonate of soda and carbonate of potash, until the whole mass is in quiet fusion. Raise the heat to bright red and pour into an iron mold, saving the crucible. Cool, break up the crucible into small pieces and transfer along with the fused mass to a 6 in. agate ware casserole (agate ware is preferable to porcelain to avoid subsequent "bumping.") Add 200 cc of distilled water and digest for one hour at a temperature near the boiling point, breaking up the fused lump with a thick glass rod. If at the end of this time any undecomposed lumps are noticed, remove them with pincers and grind in an agate mortar and wash back into the casserole with hot water. Now boil for ten minutes and filter through a loose filter into a beaker of about one liter capacity. Wash first with hot water, then with a hot solution of ammonium carbonate. The residue is now discarded, Add to the filtrate 10 grams of ammonium carbonate, and boil five minutes, and afterwards allow to stand in the cold for two hours. Filter through a loose filter into a 6-in. agate ware casserole (decanting as much as possible of the fluid) and wash with cold water once or twice. Now, to eliminate final traces of silica add 20 cc. of an emulsion of zinc oxide in ammonia and boil, leaving the casserole uncovered, until no more odor of ammonia is detected.

Filter into a No. 5 beaker and wash with hot water. To the filtrate add a solution of calcium chloride, stirring the while with a rubber tipped glass rod, until no more precipitate is formed. Allow the precipitate to subside, and filter, washing with hot water. Test the filtrate for carbonates and fluorine with a few drops of calcium chloride solution. Now transfer the precipitate along with the filter paper to a platinum dish of suitable size. Dry first, then ignite at a red heat for 20 minutes. Cool and disintegrate the mass with hot water. Add acetic acid until the solution is clear and evaporate to dryness, being careful not to scorch. Now moisten again with acetic acid and evaporate until there is no more perceptible odor of acetic acid.

"Wash the mass into a No. 3 beaker with hot water, adding hot water until the lime acetate is all dissolved and finally 150 cc. excess of hot water and stir. Digest for a few

minutes in a warm place on the hot plate and filter, washing first with hot water then with hot ammonium chloride solution, and again with hot water. Transfer the precipitate along with the filter paper to a platinum dish, dry and ignite. Cool, moisten with cold water, add 6 cc. of strong sulphuric acid, and heat for a few minutes. Cool, add 3 cc. of hydrochloric acid, heat for a few minutes. Cool, dilute and transfer the contents of the dish to a No. 2 beaker. Add five grams of ammonium chloride, boil for a few minutes, cool and add an excess of strong ammonia water. Add 2 or 3 cc. of strong peroxide of hydrogen solution, boil and filter. The lime is then precipitated from the filtrate with ammonium oxalate and the amount determined as CaO, in the usual manner, by titration with the permanganate solution. Calculate the CaO to CaF_2 from which the amount of fluorine can be readily calculated.

"To calculate CaO to CaF_2 multiply the percentage of CaO found by 1.392. Multiply the percentage of CaF_2 found by .4872, which will give the percentage of fluorine."

The following critical study of alkalimetric estimation of silicon fluoride, by Albert Hileman (in Contributions from the Kent Chemical Laboratory of Yale University, cxlviii.),* will be of interest to those desiring to make rather complete direct determinations of silicon fluoride in the analysis of fluorspar or other fluorides:

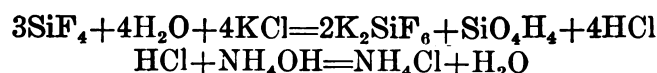
"THE ELIMINATION AND ALKALIMETRIC ESTIMATION OF SILICON FLUORIDE IN THE ANALYSIS OF FLUORIDES; BY ALBERT HILEMAN.

"The errors of the processes for the determination of fluorine, in which that element is eliminated as silicon fluoride to be subsequently estimated volumetrically, naturally fall into two categories. First, there are those errors which are due to imperfect elimination and collection of the silicon fluoride from the decomposition flask, and, secondly, there are the errors of the titration process. For the present purpose it will be most convenient to consider the latter class of errors first.

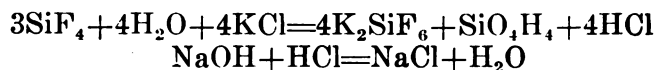
* Am. Jour. Sci — Fourth Series, Vol. XXII, No. 120, October 1906, pp. 329-338.

The Process of Titration.

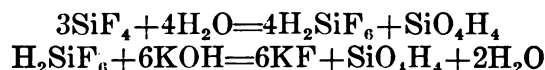
“As has been indicated, methods have been used for the determination, by volumetric process, of silicon fluoride. First, the method of Penfield, which depends upon the collection of the silicon fluoride in an alcoholic solution of potassium chloride and the titration, without removal of the precipitated potassium fluosilicate, of the hydrochloric acid set free. It is assumed that in the alcoholic solution the fluosilicic acid and potassium fluosilicate are not appreciably hydrolyzed and that ammonia may exactly neutralize the hydrochloric acid without attacking the precipitated potassium fluosilicate. Cochineal is used as the indicator.



“The second method of titrating the silicon fluoride, resembling that of Penfield, except that standard sodium hydroxide or potassium hydroxide is employed instead of ammonium hydroxide in titrating the free acid, which is the method of Bullnheimer* and used by Treadwell and Koch†, involves very similar reactions.



“The third method, that of Offerman‡ differs from the preceding methods in this respect, that the silicon fluoride is allowed to act upon water and the fluosilicic acid and hydrofluoric acid thus formed are acted upon by standard potassium hydroxide to the point of complete hydrolysis of the fluosilicate to the condition of a fluoride.



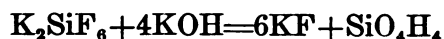
“According to this process the amount of the standard alkali used is three times as great as that used to the end reaction of the preceding process. According to a fourth

* Zeitschr. Angew. Chem. 101, 1901.

† Zeitschr. Anal. Chem. XLIII, 444, 1904.

‡ Zeitschr. Angew. Chem. 615, 1890.

method advocated by Tammann,* and useful when fluorides are to be determined in the presence of carbonates, the potassium fluosilicate is precipitated and separated with precautions and titrated by itself with standard potassium hydroxide to the point of formation of potassium fluoride and silicic acid.



“This process is essentially similar to the second process so far as concerns the reaction involved, but only two units of the alkali used for neutralization are of the standard alkali. For the present purpose, therefore, it will suffice to compare the first three methods as to the degree of agreement and the processes. For this purpose measured portions of a solution of fluosilicic acid were treated according to the methods described and the results are recorded in the following table:

TABLE I.
TITRATION IN ALCOHOLIC SOLUTION.

H_2SiF_6 cm ³	(According to Penfield) Standard NH_4OH cm ³	Standard KOH cm ³	(According to Bullnheimer) Standard NaOH cm ³	Fluorine Found grm.	Average grm.
25	7.8	----	----	0.1433	0.1429
25	7.8	----	----	0.1433	
25	7.27	----	----	0.1429	
25	7.28	----	----	0.1419	
25	7.29	----	----	0.1431	
25	----	10.67	----	0.1412	0.1411
25	----	10.72	----	0.1419	
25	----	10.64	----	0.1408	
25	----	10.67	----	0.1412	
25	----	10.60	----	0.1408	
25	----	----	9.11	0.1416	0.1415
25	----	----	9.12	0.1418	
25	----	----	9.07	0.1410	
25	----	----	9.10	0.1414	
25	----	----	9.12	0.1418	

“The differences between the amounts of fluorine indicated by the individual determinations in any one of these processes are generally slight. The averages of the determinations by potassium hydroxide and sodium hydroxide are very close together, being 0.1411 grams and 0.1415 grams of

* *Zeitschr. Anal. Chem.* XXIV, 1885, p. 328.

fluorine. The average of the titrations by ammonium hydroxide is a little higher, namely 0.1428 grams. That the difference between these averages are due to gradual variations in the reading tint, is shown by a comparison of three titrations as nearly simultaneously as possible, in which the greatest care was taken to bring all to the same tint at the final reading.

TABLE II.

COMPARISON OF SIMULTANEOUS TITRATIONS IN ALCOHOLIC SOLUTION.

	Solution used	
	cm.s	gram.
Titration by NH_4OH	7.2	0.1414
Titration by KOH	10.71	0.1418
Titration by NaOH	9.18	0.1419

So it appears that the results obtained are practically the same by the three processes of neutralization applied to a solution of fluosilicic acid. But it is to be observed that all are possibly subject to a common and constant error due to the presence of hydrofluoric as well as fluosilicic acid. If the former acid is present it tends to raise the apparent value of the latter.

“With these results of titrations in alcoholic solution are to be compared the results obtained by the method of titration in the water solution (in which the fluosilicate is completely converted to fluoride), recorded in the following table:

TABLE III.

TITRATIONS OF FLUOSILICIC ACID IN WATER SOLUTION.

(According to Offerman.)

H_2SiF_6 Taken cm.s	Standard. KOH cm.s	Standard. NaOH cm.s	Fluorine Found. gram.	Average gram.
25	80.9	-----	0.1858	
25	80.8	-----	0.1858	0.1855
25	80.9	-----	0.1858	
25	80.79	-----	0.1858	
25	-----	26.2	0.1857	0.1856
25	-----	26.15	0.1855	
25	-----	26.25	0.1860	
25	-----	26.2	0.1857	
25	-----	26.18	0.1854	
25	-----	26.14	0.1854	
25	-----	-----	-----	

“It is obvious that the process of titrating fluosilicic acid in water solution yields uniform indications, both with potassium hydroxide and sodium hydroxide, but that the values

for fluorine are very much below those of the titrations in alcoholic solution. And this would be the case if the solution of fluosilicic acid contains hydrofluoric acid as is natural.

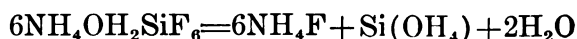
"In the analytical process in which silicon fluoride is passed into the alcoholic solution of potassium chloride the formation of hydrofluoric acid is likely to be at a minimum and so the titration of the hydrochloric acid set free in this metathesis should indicate closely the actual amount of fluorine present. If, however, the silicon fluoride is passed into water instead of into this alcoholic solution of potassium chloride, it is necessary to titrate together the products of action, fluosilicic acid and hydrofluoric acid, to the point of formation of the alkali fluoride, in order that the indication may be correct.

The action of ammonium hydroxide upon fluosilicic acid in water solution proves to be comparable with that of sodium hydroxide, and inferentially with that of potassium hydroxide, though the hydrolysis of the fluosilicate appears to be not quite so complete. In the table are given the results of comparative titrations.

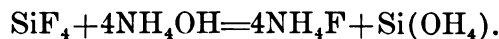
TABLE IV.

H ² SiF Taken cm. ³	NH ₄ OH (1cm ³ =0.006647) cm. ³	Flourine found by NH ₄ OH grm.	Flourine found by NaOH grm.
25	81.04?	0.2032	0.2057
25	81.00	0.2090	0.2057
10	12.89	0.0811	0.0823
10	12.42	0.0816	0.0823
10	12.42?	0.0811?	0.0823

The following expression represents the reaction:



"When silicon fluoride is passed into water containing ammonium hydroxide, as is suggested in Liversidge's method for the analysis of fluorides, it is obvious that nearly complete hydrolysis must take place, with formation of silicic acid precipitated or colloidal, according to the equation,



According to Liversidge,* potassium fluosilicate may be

*Chem. News XXIV, 246.

thrown down by addition of potassium chloride and alcohol, after dissolving the precipitated silica by heating the ammoniacal liquid. In my experience, it has never been possible to thus dissolve all the silica, and the precipitate obtained by adding potassium chloride, with or without alcohol, appears to be silica thrown out of its colloidal solution by addition of the electrolyte.

THE ELIMINATION OF SILICON FLUORIDE.

“As to the sources of error due to imperfect elimination, and collection, of silicon fluoride, we have the testimony of the several investigators already quoted. The importance of using the fluoride in the finest state of division, of having the sulphuric acid evolved from the decomposition flask, and of using quartz for the silicon dioxide in the decomposition flask, have all been emphasized. Many forms of apparatus have been employed and the results have varied widely, errors of from 0.0010 gram to 0.0050 gram in determination of fluorine by absorption and weighing of silicon fluoride being not uncommon.

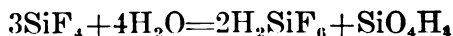
“At the outset of the work to be described, an investigation was made as to the limit of error likely to occur in the use of simple apparatus and sulphuric acid, prepared by heating to the fuming point, for about a half hour. The silicon fluoride evolved was estimated by absorption in an alcoholic solution of potassium chloride following the method of Penfield,* and the hydrochloric acid set free was estimated by standard potassium hydroxide.

“The apparatus employed consisted of the following parts: First, there was an apparatus for purifying the air current by passing in through a sulphuric acid wash bottle and two large drying cylinders containing fused calcium chloride at the bottom and soda lime at the top; second, a 100 cm³ decomposition flask provided with a double perforated rubber stopper, through which passed a glass tube from the drying cylinders to the bottom of the flask, while another tube, leading from this decomposition flask, was joined to a large empty U-tube intended to condense any sulphuric acid which might be carried from the decomposition flask. Third, connected

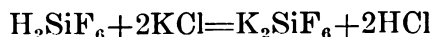
* *Am. Chem. Jour.*, 1, 27.

with the outer limb of the U-tube for condensing sulphuric acid was an absorption system similar to that described by Burk.* It consisted of a test tube 34 cm. in length and 2 cm. in diameter, containing a few cm³ of mercury into which extended a delivery tube with a capillary opening. The test-tube was placed at an angle to diminish the pressure throughout the system.

“Before making a determination, the apparatus was first carefully dried. The absorption tube was filled with a saturated solution of potassium chloride in 50 per cent. alcohol, and the material to be analyzed, weighed on a watch glass, was transferred to the decomposition flask through a funnel with a short neck. To the material were added fifteen times its weight of ignited quartz sand and 50 cm³ of sulphuric acid, which had been previously heated strongly and cooled in a desiccator. To an iron plate supporting the decomposition flask, heat was applied by a burner and regulated so that a flask of sulphuric acid placed where it received the same amount of heat as the decomposition flask should have a temperature of between 150° and 160°. During the heating a slow current of air was passed through the apparatus. In the reaction in the decomposition flask hydrofluoric acid was generated which acting on the silica formed silicon fluoride. In the absorption tubes silicon fluoride acted on water according to the following equation:



In the presence of potassium chloride and alcohol the fluosilicic acid was precipitated as potassium fluosilicic, and a corresponding amount of hydrochloric acid set free.



The hydrochloric acid was then titrated with a standard potassium hydroxide solution, using cochineal as an indicator.

“A series of experiments, carried out in the manner described, was made with ordinary pulverized fluorite. The heating was continued in every case above the time limit of two

* Jour. Am. Chem. Soc. XXIII, 825 (1901).

hours. All gas bubbles had disappeared from the acid mixture, which fact, according to Fresenius* and Offermant† shows that the decomposition was complete.

"The time required to decompose fluorite is stated by Penfield to be two hours from 0.2 to 0.1 gram; by Fresenius two hours for 0.1 gram and four hours for 1.0 gram.

TABLE V.

	CaF ₂ grams.	Silica grams.	KOH cm ³ . (1cm ³ =0.01045F.)	Theory Fluorine grams.	Found Fluorine grams.	Error Fluorine grams.
1.	0.5000	7.0	22.7	0.2482	0.2872	-0.0060
2.	0.5000	7.0	22.56	0.2482	0.2857	-0.0075
3.	0.5000	7.0	22.7	0.2482	0.2872	-0.0060
4.	0.5000	7.0	23.15	0.2482	0.2419	-0.0013
5.	0.5000	7.0	22.4	0.2482	0.2840	-0.0092
6.	0.5000	7.0	21.7	0.2482	0.2277	-0.0155
7.	0.5000	7.0	22.	0.2482	0.2299	-0.0183
8.	0.5000	7.0	21.7	0.2482	0.2267	-0.0165
9.	0.5000	7.0	22.5	0.2482	0.2351	-0.0081

"The cause of the variation in the results, and of the occasionally very large errors in the above series of experiments was not apparent at the time when experiments were made, but reference will be made to this later.

"Crystals of fluorite, perfectly clear and of pale green color, were next tried. The powdered mineral on treatment with sulphuric acid yielded the theoretical amount of calcium sulphate.

TABLE VI.

	CaF ₂ grams.	KOH cm ³	Fluorine Theory grams. (1cm ³ =0.01045 Fluorine.)	Fluorine Found grams.	Fluorine Error grams	Time hours.	Tem- pera- ture.
1.	0.5000	21.77	0.2482	0.2274	-0.0168	6	150°
2.	0.5000	22.0	0.2482	0.2299	-0.0183	6	
3.	0.5000	21.77	0.2482	0.2274	-0.0188	8.25	
4.	0.5000	23.6	0.2482	0.2466	+0.0084	6	160°
5.	0.5000	22.15	0.2482	0.2314	-0.0118	6	
6.	0.5000	22.19	0.2482	0.2318	-0.0114	6	
7.	0.5000	19.37	0.2482	0.2014	-0.0418	6	180°
8.	0.5000	16.2	0.2482	0.1692	-0.0740	3	
9.	0.5000	22.2	0.2482	0.2325	-0.0107		
10.	0.5000	21.25	0.2482	0.2220	-0.0212		boil- ing.

"In experiment (1) above, the heating was continued for six hours at 150—160°. In experiment (2) the powdered mineral was fused with sodium carbonate and the mixture trans-

* Zeitschr. Anal. Chem., VI, p. 190.

† Loc. Cit.

ferred to the decomposition flask. In experiments 5--8 above, the temperature was raised as high as 180° , while the empty U-tube was immersed in a freezing mixture of salt and ice. Blank determinations showed that some sulphuric acid was carried over under these conditions. In experiment (9) and (10) the acid was heated to boiling and allowed to cool before the air current was passed through.

"The effect of precipitated silica instead of quartz sand was next tried. In experiment (1) the silica was air dried; in (2) it was strongly ignited.

TABLE VII.

	CaF ₂ grams	Silica grams	KOH cm ³	Theory Fluorine grams	Found Fluorine grams	Error Fluorine grams
1.	0.5000	7.0	6.4	0.2432	0.0668	0.1764
2.	0.5000	7.0	21.2	0.2432	0.2215	0.0217

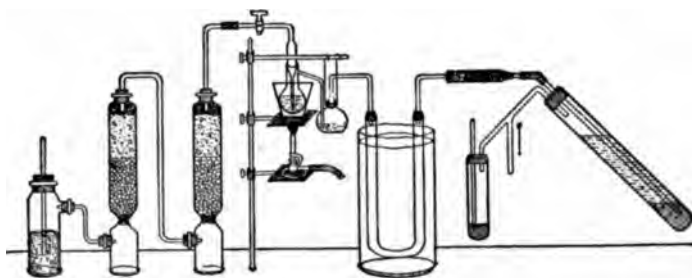
"These experiments indicate that the small amount of water in the air dried silica may cause great deficiency in the fluorine found, and suggests the idea that even the amount of water produced in the reaction involving the sulphuric acid, the fluoride and silicon dioxide may be the occasion of trouble.

APPARATUS FOR USE AT HIGH TEMPERATURES.

"Owing to the lack of success with the silicon fluoride processes in which the decomposition was effected at temperatures between 150 — 160° , an attempt was made to devise a simple and convenient form of apparatus in which the acid mixture might be heated to boiling to facilitate the removal of the silicon fluoride to the absorption system.

"After a number of experiments with this end in view the following model of apparatus was found to be the most satisfactory: A glass stopper, made by drawing out a glass tube 1 cm. in diameter and sealing a small glass tube on each end, is ground into a 70cm³ side neck flask. To one end is sealed a glass stop-cock. The other end extends to the bottom of the flask. The side neck is sealed to a Voit flask. The length of the tube between the two flasks is 17 cm, and it is bent at right angles, 12 cm from the Voit flask. The tube leading from the Voit flask enters a large empty U-tube through a rubber stop-

per. A tube from the other limb of the U-tube enters a trap loaded with phosphorus pentoxide. A rubber connection joins the trap with the delivery tube of the absorption apparatus described above. Connected with the absorption tube is a pressure regulator. This consists of a T-tube, one opening of which enters a test tube of mercury through a rubber stopper. Another perforation is closed with a glass tube which may be raised or lowered in the mercury. The third opening of the T leads to the aspirating pump.



“Preparatory to making a determination the apparatus is carefully dried. The tip of the delivery tube is then placed beneath the surface of the mercury in the absorption tube and distilled water is added, care being taken that enough space remain for the rise in level when air bubbles are in the liquid. The pressure regulator is then connected with the absorption tube and adjusted so that a rise of pressure in the apparatus should be relieved but no appreciable vacuum created. The U-tube is then immersed in a vessel of cold water and connected with the trap. Next, the mineral, together with quartz powder in about three times the weight of the fluorine present, is transferred to the decomposition flask. Next, enough sulphuric acid to seal the delivery tube from the side neck flask is introduced into the Voit flask. The two flasks are then tilted so that acid should moisten the connecting tube to the bend. About 40 cm³ of sulphuric acid and several capillary tubes 1 mm in diameter sealed 1 cm from an open end and at the other end* to prevent bumping, are added to the decomposition flask, and the stopper quickly replaced and sealed with a drop of sulphuric acid. The acid used above had been boiled

* Scudder, J., Am. Chem. Soc. XXV, p. 118

for half an hour and a current of dry air passed through on cooling. A thin strip of asbestos is wrapped about the neck of the flask, and the stop-cock having been closed, the bulb is heated in a radiator whose top is covered with a sheet of asbestos matting.

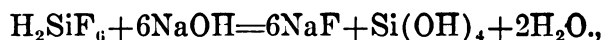
“When heat is applied to the process, bubbles of gas are given off, the solid material rises to the surface, and during the course of the heating an oily film gathers on the upper part of the flask and in the delivery tube. On boiling, this film is replaced by a white deposit which receded before the acid vapors. The success of the determination depends, as was found, on the removal of this deposit. When the acid vapors have penetrated the length of the tube leaving it clear or translucent, the decomposition is complete, and the stop-cock having been opened, the side neck flask is cooled to about 75°. A current of purified air is drawn through the apparatus, slowly at first and then more rapidly. About six liters are necessary to remove the last trace of silicon fluoride.

“Daniels”^{*} suggestion that the deposit mentioned above is a polymer of SiF_4 appears unwarranted. It seems more probable that this is a product of partial hydrolysis of silicon fluoride by the action of water generated in the action of sulphuric acid on the fluoride, as suggested above, the process of forming and hydrolyzing silicon fluoride being repeated until the water is finally absorbed in the cold acid of the Voit flask.

“If it happens that the acid mixture bumps before the decomposition is complete, some of the deposit may become dislodged from the tube and remain undecomposed in the Voit flask. Bumping also renders it difficult to boil the acid vapors through the delivery tube. On this account the tube between the two flasks should be as short as is practicable. Unsatisfactory results were obtained when the tube was about one-half longer than the dimensions given above. If the acid tends to suck back from the Voit flask, it is arrested by opening the stop-cock for a moment to relieve the vacuum. If, at this point of the experiment, the pressure regulator should not be adjusted properly, acid vapors would be drawn through

^{*}*Zeitschr. Anorg. Chem.* XXXVIII, p. 257.

the apparatus into the absorption tube. The decomposition is ended in fifteen to forty minutes. The delivery tube is washed and the absorption solution transferred to a flask and titrated with sodium hydroxide* from an alkali burette, with phenolphthalein as an indicator, according to the method of Offerman, the third method referred to above.



“The following series of results was obtained according to the method outlined above.

TABLE VIII.

	CaF ₂ grams	Quartz grams	Na OH cm ³ (1cm ³ =0.005123F.)	Theory Fluorine grms.	Found Fluorine grms.	Error Fluorine grms.
1.	0.3000	0.4	28.2	0.1459	0.1444	-0.0015
2.	0.3000	0.4	28.35	0.1459	0.1452	-0.0007
3.	0.3000	0.4	28.34	0.1459	0.1451	-0.0008
4.	0.3000	0.4	28.25	0.1459	0.1447	-0.0012
5.	0.3000	0.4	28.3	0.1459	0.1449	-0.0010
6.	0.3000	0.4	28.37	0.1459	0.1453	-0.0006
	NaF					
7.	0.3000	0.4	26.2	0.1356	0.1342	-0.0012
8.	0.3000	0.4	26.44	0.1356	0.1355	-0.0001
9.	0.3000	0.4	26.46	0.1356	0.1356	-0.0000
10.	0.3000	0.4	26.3	0.1356	0.1347	-0.0009
11.	0.3000	0.4	26.34	0.1356	0.1349	-0.0007
12.	0.3000	0.4	26.3	0.1356	0.1347	-0.0009
		Ignited Silicic acid				
13.	0.3000	0.4	26.29	0.1356	0.1346	-0.0010
		Quartz				
14.	0.3000	0.4	26.3	0.1356	0.1347	-0.0009

Ca, 40.1; Na, 28.05; F, 19. (Error—0.0008).

“With the apparatus described above, in which the sulphuric acid in the decomposition flask may be boiled, the silicon fluoride formed passes rapidly to the absorption system, other products of partial hydrolysis of silicon fluoride formed in the flask or tube are ultimately reconverted to silicon fluoride, and regular results of a fair degree of accuracy are obtained. In all the experiments above except (6) and (14) phosphorus pentoxide, about 2.0 grams, was introduced into the decomposition flask, the purpose being to retain water formed in the reaction. The results of the experiments specifically mentioned show, however, that phosphorus pentoxide in the flask is not essential.

* Kuster, Zeitsche. Anorg. Chem. **XLI**, p. 475.

"In three blank experiments, where the acid in the decomposition flask was heated to boiling, amounts of acid in each case equivalent to 0.0002 gram of fluorine were found in the absorption solution; the above results therefore are subject to this trifling error.

HILLEBRAND ON DETERMINATION OF FLUORSPAR.

For the determination of minute quantities of fluorine in the analysis of silicate and carbonate rocks, the methods described by Dr. W. F. Hillebrand in Bulletin 305 of the U. S. Geological Survey are, perhaps, the best available, giving as they do the result of long experience in the Survey laboratory. Following is Hillebrand's account of the methods:

IN SILICATE ROCKS.

"A. Imperfection of the Qualitative Test for Fluorine.

"There is no qualitative test which will reveal with certainty the presence of fluorine in rocks. Heating the powder before the blow-pipe with sodium metaphosphate on a piece of curved platinum foil inserted into one end of a glass tube, or in a bulb tube, is not to be relied on in all cases. While as little as 0.1 per cent. of fluorine can sometimes be thus detected with ease, much larger amounts in another class of rocks may fail to show.

"B. Quantitative Determination of Fluorine.

"a. The Method.

"For the reason that the fluorine minerals occurring in rocks are mostly attacked but partially, if at all, by strong hot sulphuric acid, none of the methods depending on the volatilization of silicon fluoride can be used. There is the further reason that even with decomposable fluorides it is impossible to obtain quantitative results in presence of amorphous silica or silicates.* Only with quartz powder is volatilization perfect. The method to follow is that of Berzelius,

* "See Daniel, K., *Zeitsche. Anorg Chemie.* Vol. 88, 1904, pp. 257-306."

which, though not difficult, requires great attention to details and even then affords low results (see *c.* for causes of error). It admits of the determination of silica at the same time, and is in fact the only method available for silica in fluorides.

"Two grams of the rock powder are fused with four to five parts of sodium-potassium carbonate free from fluorine, avoiding the use of a blast if possible. For minerals rich in fluorine and low in silica it may be necessary to add pure silica before fusing in order to effect complete decomposition of the fluoride, just as with the alkaline-earth phosphates. But this will probably never be required in ordinary rock analysis. To the aqueous extract, containing fluorine and usually much of the silica besides other bodies, several grams of ammonium carbonate are added, the liquid is digested at a gentle heat (40°) for some time, and on cooling more carbonate is introduced.* After twelve hours the precipitate is collected and washed with water containing ammonium carbonate. From the filtrate the excess of the latter is expelled by evaporating nearly to dryness and the somewhat diluted solution is brought toward neutrality as follows, according to the direction of Treadwell. A few drops of phenolphthalein are added, then nitric acid (not hydrochloric in this case, see below) till the red color disappears. The solution is now boiled, the color re-appearing, to be again discharged by acid on cooling. These operations are repeated till it requires but 1 to $1\frac{1}{2}$ cm³ of $\frac{2}{N}$ acid to discharge the color. There is now added 1 to 2 cm³ of an ammoniacal solution of zinc oxide,† and the liquid is boiled till the ammonia is wholly expelled.

* "The use of ammonium nitrate on chloride, instead of carbonate, for throwing out the silica and alumina is not to be recommended because of loss of fluorine on subsequent evaporation (H. Rose)."

† "Made by precipitating pure zinc-chloride solution with potassium hydroxide, filtering, washing and dissolving the precipitate in ammonia. If the rocks are very basic, it may happen that the amount of silica in the alkaline solution of the fusion is so small that ammonium carbonate may be dispensed with and the zinc-oxide solution added at once, after neutralizing as above.

"Instead of the ammoniacal zinc-oxide solution, F. Seemann (Zeitschr. anal. Chemie, Vol. 44, 1906, p. 843, advocates using the Schaffgotsch solution in which has been dissolved in the cold 20 grams of freshly precipitated mercuric oxide to the liter. For every 0.2 gm of dissolved silica 100 cm³ of this reagent are to be used. The solution is then to be evaporated to complete dryness, the residue taken up with water, filtered and washed, the filtrate again neutralized with hydrochloric acid [nitric in rock analysis—W. F. H.], and again evaporated to remove the last of the silica. Where silica is to be determined at this stage this reagent has the advantage over the zinc solution that direct ignition of the precipitates (under a good draft hood) yields at once silica. Its use is manifestly allowable in rock analysis only after the alumina has first been separated by ammonium carbonate.

The precipitate, containing the last of the silica and some phosphorus, in addition to that thrown down with the alumina by ammonium carbonate, is separated and washed with water.

"The above-prescribed use of nitric instead of hydrochloric acid for neutralizing is necessitated by the fact that phosphorus, which is almost invariably present, and chromium must still be removed, and this can be done only from a nitric solution as follows: To the still alkaline solution silver nitrate is added in excess, whereby phosphate, chromate, chloride if chlorine is present, and carbonate of silver are precipitated. The last serves to correct any acidity resulting from the reaction between the alkaline phosphate and the silver salt, thus producing the neutral solution needed for complete precipitation of the phosphate and chromate. After slight heating and filtering, the excess of silver is removed by sodium chloride and 1 cm³. of $\frac{2}{3}$ sodium-carbonate solution is added to the filtrate, which is then boiled in a dish of good size with a large excess of calcium-chloride solution. At this stage there must be no ammoniacal salts in solution, otherwise calcium fluoride may be held up. The precipitate consists of a mixture of calcium carbonate and fluoride, the former serving to aid filtration of the latter. The precipitate is collected on paper and washed with hot water, dried, and ignited separately from the filter as far as possible. If the dish used for the precipitation was of platinum it is not necessary to cleanse it from adhering precipitate, but the contents of the filter are washed back into the dish, the liquid in this is evaporated away, the ash of the filter added, and the dish heated over a free flame to faint redness for a few moments.

"Dilute acetic acid is now poured upon the thus gently ignited mixture in small quantities at a time and in amount slightly in excess of that needed to dissolve the calcium carbonate. When visible action ceases the liquid is evaporated to dryness and the residue taken up with hot water and a drop of acetic acid, filtered, dried, and gently ignited.

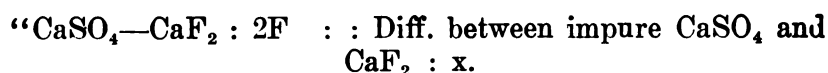
"The amount of fluoride obtained from rocks being usually very small, a single treatment as above suffices, but for the larger amounts obtained from fluorine minerals a second and even third treatment with acetic acid may be needed, filtering and igniting after each. S. L. Penfield and J. C. Minor* found

* Am. Jour. Sci., 3d Ser., Vol. 47, 1894, p. 889.

in such cases that if a great excess of acetic acid is used at the start the results are lower than by the repeated treatment. For considerable amounts, when the loss between two treatments is reduced to not more than half a milligram, F. P. Treadwell and A. A. Koch* take the next to the last weight as correct.

“b. Testing of the Calcium Fluoride.

“The well-washed and gently ignited calcium fluoride finally obtained in the course of this method should be converted to sulphate as a check on its purity, and at the same time as a qualitative test to ascertain if it really is calcium fluoride by the characteristic odor of the gas given off. Should fluorine be found, and the weight of sulphate not correspond to that of the fluoride, the former should be dissolved in hot nitric and tested for phosphorus by ammonium molybdate solution. If phosphate is absent the impurity may have been silica or calcium silicate—which of these it would be difficult to decide. In the former case the fluorine might be safely deduced from that of the sulphate, but not in the latter. If the rock were rich in sulphur it might happen that calcium sulphate would be thrown down with the fluoride, but this should be removed by thorough washing. If not, and it were certainly the only impurity present, the fluorine could be calculated, after conversion of the fluoride into sulphate, by the formula:



“It is an exceptional case when there is exact agreement between the weight of fluorine and sulphate, and with the small amounts usually met in rocks the error may be an appreciable one in percentage of fluorine, though of no great significance otherwise.

c. Accuracy of the Method.

“It is evident from the above that if the greatest care is not taken to prevent any kind of contamination of the weighted fluoride the error in the small amounts in question may be

* Zeitschr. Anal. Chemie, Vol. 43, 1904, p. 469.

very great. If phosphate were present it would not do to apply the check by conversion to the sulphate, because the evaporation with sulphuric acid and following ignition would volatilize metaphosphoric acid.

"There is another source of error due to the solubility of the fluoride itself in water and acetic acid. F. P. Treadwell and A. A. Koch have investigated the solvent effect of these and some other reagents. They find it possible to detect additional fluorine by repeating the precipitation with calcium chloride in presence of sodium carbonate, and the total errors to be such that for 5 milligrams CaF_2 or less the results are much too low, though the qualitative detection can be still made in 100 cm^3 of solution with only 0.0009 gram CaF_2 , notwithstanding the fact that the quantitative tests had seemed to indicate that the loss would be about 0.0015 gram CaF_2 for every 100 cm^3 , including wash water. It thus appears that with 1 gram of sample amounts of less than 0.04 to 0.05 per cent. of fluorine will entirely escape observation.

"A source of error not generally known arises whenever calcium fluoride is ignited in contact with paper. Fluorine escapes to a slight extent and is replaced by oxygen this reaction being doubtless due to the action of water vapor and not to oxygen of the air.

"F. Seeman* has subjected all the known methods of determining fluorine to extended examination, using calcium fluoride as his test material, and declares the Berzelius method to be far inferior to those based on volatilization of the fluorine as silicon fluoride, by reason of great and varying losses, the causes of which he was unable to satisfactorily trace. He was unable to recover by it more than about 87 to 89 per cent. of the fluorine. My tests do not confirm his very unfavorable results. I was able repeatedly to regain 95 to 98 per cent. of the fluorine. To do so requires, however, re-fusion of the residue left after leaching the alkali-carbonate melt, including in the same re-fusion the silica precipitated by ammonium carbonate and ammoniacal zinc oxide, the treatment of the filtrate from the precipitate of calcium carbonate and calcium fluoride with additional sodium carbonate and calcium chloride, and the re-evaporation of the acetic acid solutions of the precipitated calcium carbonate.

* *Zeitschr. Anal. Chemie*, Vol. 44, 1905, p. 343.

"C. Determination of Silica.

"The several precipitates obtained by ammonium carbonate and zinc oxide, together with the residue from the original alkali fusion, are dissolved as far as may be in hydrochloric acid, the papers ignited and their ashes added, and silica separated by the processes detailed in 6, page 68 (of U. S. G. S. Bulletin 305). These may be greatly simplified, if bases are not likewise to be determined, by evaporating the first filtrate from the silica with much sulphuric acid as in the last part of f. a., page 88 (U. S. G. S. Bulletin 305).

IN CARBONATE ROCKS.

"As with silicate rocks, an exact determination of fluorine in carbonate rocks is difficult if not impossible with our present methods, and little or nothing has been done along this line.

"Because of the great preponderance of lime, direct fusion with sodium-potassium carbonate and silica is of somewhat doubtful practicability. Probably the following treatment will afford the best results.

"Dissolve the powder in dilute acetic acid, as far as this may be possible without boiling, and filter. To the filtrate add solution of sodium carbonate till in some light excess, boil, and treat the precipitate of calcium carbonate and possible fluoride as on page 157 (of Bulletin 305). Most of the fluoride that may have been dissolved by the acetic acid will thus be found. The silicious matter insoluble in acetic acid is fused with sodium-potassium carbonate and further treated as in B. a." (Reference is to "a. The Method," under "B. Quantitative Determination of Fluorine" on a preceding page).

CHAPTER VIII.

LIST OF MINES, MILLS AND OPERATORS.

For convenience of reference, and in order to economize space, the following lists of lead, zinc and spar mines, and concentrating and grinding plants in Western Kentucky are presented in tabular form. Following them is given a list of present operators and holders of mining lands in the district, with post-office addresses, etc.

LEAD, ZINC AND SPAR MINES IN WESTERN KENTUCKY.

LOCATION, OWNERSHIP, HISTORY, SYNONYMS.

CRITTENDEN COUNTY.				
No.	Name of Mine.	Location.	Operator.	Title.
1	Ada Florence mine...	5 m. W. of Marion...	The Great Northern Mining & Milling Co	F
2	Alice mine	10 m. N. W. of Marion	Alice Mining Co ...	F
8	Akers prosps	5 m. N. W. of Marion	J. G. Rochester and others	L
4	Asbridge mines.....	2 $\frac{3}{4}$ m. S. W. of Mexico	Blue Grass Fluor-spar Co	L
5	Babb shafts..... (T. J.)	11 m. S. W. of Marion	C. & A. T. Pope	MR
6	Barger shaft.....	9 m. N. N. W. of Marion	D. B. Barger.....	F
7	Barger prosps..... (T. J.)	9 m. N. N. W. of Marion	Wm. Spencer.....	F
8	Beard mine	8 m. N. N. W. of Marion	P. E. Beard.....	F
9	Beard Incline.....	8 $\frac{1}{2}$ m. N. N. W. of Marion	Cordelia Beard and others	F
10	Belt dike prosp	3 m. S. W. of Marion...	Asa Belt.....	F
11	Belt-Sullenger prosp	8 m. N. N. W. of Marion	Harpending and others	L
12	Ben Belt mine	10 $\frac{1}{2}$ m. W. of Marion	Marion Zinc Co	L
13	Bertha May Shaft...	8 m. S. W. of Marion.	Crider & Others...	L
14	Bibb Shaft	1 $\frac{1}{4}$ m. N. W. of Marion	James Henry	L
15	Big Four Shafts.....	9 m. W. of Marion ..	Big Four Mining, Milling & Development Company	L
16	Big Four mine.....	8 m. W. of Marion...	Big Four Mining & Development Company	F

LEAD, ZINC AND SPAR MINES IN WESTERN KENTUCKY.

LOCATION, OWNERSHIP, HISTORY, SYNONYMS.

CRITTENDEN COUNTY.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
*1902	Western Kentucky Mining Co	1906	Widow Franks	1
1902	Marion Zinc Co	1906	J. O. Belt Shaft	2
*1901	Crittenden County Lead, Zinc & Spar Co	1902	.....	3
†1899	Kentucky Fluorspar Co.	1906	.....	4
1900	?W. S. Lowery	1905	.....	5
1895	S. W. Cooley	1904	.....	6
1895	S. W. Cooley	1895	.....	7
†1882	Cincinnati Lead & Spar Co. .	1901	Kentucky No. 4, Beard E. of road	8
1895	S. W. Cooley	1904	Cordelia Beard	9
1902	W. S. Lowery	1902	.....	10
-----	-----	-----	Joe Lindsey place	11
1880	Belt & Sullenger	1905	.....	12
†1900	Western Kentucky Mining Company	1904	Marion Beard	13
*1899	J. W. Waggoner	1902	G. R. Bibb	14
1902	Givens Mining Company	1904	C. C. Bebout, prosps.	15
†1898	J. C. Miller	1904	J. C. Miller Shafts	16

CRITTENDEN COUNTY—Continued.

No.	Name of Mine.	Location.	Operator.	Title.
17	Blue Heirs 11 Acre prosps.	5 m. N. W. of Marion	Blue Heirs	F
18	Brown mines	7 m. S. W. of Crayneville	Kentucky Fluorspar Company	L
19	Bryant Dike prosps.	8 m. W. of Marion	Harpending and others	L
20	Bush Prosps.	9 m. W. of Marion	Western Clay & Mining Company	F
21	Butler prosps.	12 m. S. W. of Marion	Albany Mining & Investment Company	L
22	Cardin Dike prosps.	6 to 6½ m. S. W. of Marion	A. H. Cardin	F
23	Campbell prosps.	5½ m. S. W. of Mexico	T. C. Campbell	F
24	Champion prosps.	10 m. S. W. of Marion	Widow Champion	F
25	Clark prosps.	6 m. S. E. of Carrsville	W. H. Clark	F
26	Clemens prosps.	9 m. N. W. of Marion	W. P. Clemens	F
27	Clement mine	5 m. W. N. W. of Marion	F. M. Clement	F
28	Columbia mines	5 m. W. of Marion	Southern Lead & Zinc Company	SL
29	Commodore mine	6½ m N. W. of Marion	Commodore Mining Company	F
30	Cox mines	8 m. N. W. of Marion	Felix G. Cox	F
31	Crosson mines	10 m S. W. of Marion	Mrs. Leander White	F
32	Dalton props.	4 m. S. of Tolu	Temme and others	F
33	Dan. Riley mine	6¾ m. S. W. of Crayneville	Eagle Fluorspar Company	MR
34	Damron prosp.	11 m. W. S. W. of Marion	Winfield S. Damron	F

CRITTENDEN COUNTY—Continued.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1900	Western Kentucky Mining Company	1902	Blue Heirs prosps.	17
?1900	The Fluorspar Company....	1906	Brown, Pierce & Crow	18
1901	.....	1906	.....	19
1903	Western Clay & Mining Company	1903	John Franklin	20
1901	.....	1904	John Butler, Big Dick....	21
1902	Winifred Mining Company..	1904	.....	22
1903	J. L. Harris	1903	.....	23
1905	Garnett Bros.....	1905	.....	24
1902	Marion Zinc Company.....	1902	.....	25
1902	Marion Zinc Company.....	1903	.....	26
1902	F. M. Clement.....	1904	Maj. Clement shafts Bitter Apple mine.....	27
1885	Andrew Jackson.....	1906	Lead mines.....	28
1892	P. S. Maxwell and others....	1905	Dave Franks	29
1899	J. W. Waggoner.....	1906	.....	30
1899	Eagle Fluorspar Company..	1903	Crosson Cave, De Artigan, Hardigan	31
1904	Temme Mining Company....	1904	Wayman Dalton.....	32
1899	Eagle Fluorspar Company ..	1900	F. V. Hayden & Company Land.....	33
?1902	J. S. Waggoner	1903	.....	34

CRITTENDEN COUNTY—Continued,

No.	Name of Mine.	Location.	Operator.	Title.
35	Daughtery prosp.	3 m. S.S.E. of Cave-in-Rock	Louis Daughtery	F
36	Davenport Dike shaft	7 m. S. W. of Marion	Davenport Bros.	F
37	Davenport prosp. . . .	1½ m. N.W. of Mexico	Marion Zinc Company	F
38	Dean & Wilson shafts	5½ m. N.W. of Marion	Dean & Wilson	F
39	Deer Creek mine	7½ m. N.W. of Marion	Deer Creek Mining Company	F
40	Eaton mine	5½ m. S.W. of Marion	Louisville Spar, Lead & Zinc Company .	MR
41	Ebbie Hodge mine..	5 m. S.W. of Crayneville	?Rovianck & others..	F
42	Eclipse mine	5 m. W.N.W. of Marion	Eclipse Mining Company	F
43	Edwards mine	5 m. W.N.W. of Marion	Edwards Mining Company	F
44	Farmer prosps.....	3½ m. W. of Marion	James Farmer	F
45	Flanary Shaft (R.E.)	8 m. N.W. of Marion	The Crittenden Mining Company	L
46	Flanary prosps	8 m. N.W. of Marion	Harpending & others	L
47	Franklin prosps ...	0 m. S.W. of Marion	E. B. Franklin	F
48	Givens mines	9 m. W. of Marion..	Givens Mining Company	L
49	Glendale mine	6½ m. N.W. of Marion	J. M. Pearsons	L
50	Gray Shaft	11 m. W. N. W. of Marion	Widow Gray	F
51	Green prosp.	9½ m. N. of Marion	Dan. Green	F
52	Guill Shafts (Alec)	12 m. W. of Marion	The Great Northern Mining & Milling Company	L
53	Hard prosps.	1½ m. N.W. of Marion	A. Hard	F

CRITTENDEN COUNTY—Continued.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
				85
†1902	W. S. Lowery.....	1902		86
1899	J. W. Waggoner.....	1899	A. A. Davenport.....	87
†1901	Dean & Wilson	1908		88
1900	Western Kentucky Mining Company.....	1904	Widow Clark, Cartwright	89
1901	G. Wesley Eaton.....	1904	Mortgage Lifter, Automatic Mine	40
1900	M. C. O'Hara	1904	Samples mine, in part	41
1902	Crittenden County Lead, Zinc & Spar Company....	1906	McMican prosps.	42
†1902	Kentucky Fluorspar Company	1906	Panther Hollow mine, Wood's place.....	43
1902	R. C. Walker & others	1908	Hubbard prosp. in part...	44
1903	R. E. Flanary.....	1904		45
1906	Harpending & others	1906		46
*1903	Judge J. T. Cook	1903		47
*1900	Corn Brothers.....	1905	Corn mines, Cobalt prosps.	48
1901	Harry Watkins	1906	Harry Austin Land	49
1902	Western Clay & Mining Company	1903	Porter mine	50
				51
1902	The Great Northern Mining & Milling Company.....	1904		52
1900	A. Hard	1906		53

CRITTENDEN COUNTY—Continued.

No.	Name of Mine.	Location.	Operator.	Title.
54	Hardin Shaft	9¾ m. S.W. of Marion	Mrs. John Reed	F
55	Heath Prosp.	9 m. N. W. of Marion	J. H. Moore Estate	F
56	Heyward shaft	7 m. W. N. W. of Marion	Little & Macer	F
57	Hodge mines	6½ m. S. W. of Crayneville	Kentucky Fluorspar Company	F
58	Holly mines	8½ m. W. N. W. of Marion	Kentucky Fluorspar Company	F
59	Howard prosp.	5½ m. S. W. of Crayneville	Eagle Fluorspar Company	L
60	Jones prosp.	9 m. W. N. W. of Marion	Anderson Jones	F
61	King prosp.	1 m N. W. of Mexico	James King	F
62	Keyes mine	10 m. W. of Marion	Keyes & Davis	L
63	Keystone mine	5½ m. W of Marion	Keystone Mineral & Mining Company	MR
64	Koon dike prosp....	5 m. S. W. of Fredonia	J. B. Koon	F
65	Lady Farmer mines	4½ W. N. W. of Marion	The Henderson Company	F
66	LaRue prosp.	5½ m. S. W. of Marion	Charles LaRue	F
67	LaRue Heirs prosp.	5¾ m. S. W. of Marion	LaRue Heirs	F
68	LaRue prosp.	6 m. S. W. of Marion	C. & A. T. Pope	MR
69	LaRue mines	8 m. W. of Marion	Morganfield Mining Company	L
70	Leander mine	4 m. W. of Crayneville	Leander Mining Company	L
71	Leona mine	7 m. N. W. of Marion	J. M. Persons	L

CRITTENDEN COUNTY—Continued.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1900	C. M. Miller	1902	Widow Hardin	54
1904	Sed Heath	1904	.....	55
1904	Little & Macer	1904	Donakey prosps.	56
*1897	J. W. Waggoner	1906	.....	57
1899	Kentucky Fluorspar Com- pany	1906	J. W. Tilley land	58
1902	Kentucky Fluorspar Com- pany	1903	.....	59
1903	Marion Zinc Company	1904	.....	60
1901	R. B. Clement	1903	Cookseyville Church prosp.	61
1903	Keys & Davis prospected for lead years ago	1904	Henry Watson	62
1903	Keystone Mineral & Mining Company	1906	Carter land; Hopewell mine	63
1902	J. B. Koon	1904	Caldwell Springs Dike prosp.	64
1903	The Henderson Company ..	1906	Widow Farmer & Deboe prosp. in part	65
1905	Charles LaRue	1905	.....	66
1900	The Republic Mining Com- pany	1902	.....	67
1905	C. & A. T. Pope	1905	R. A. LaRue	68
*1874	James & Thomson	1906	Widow Love, in part	69
†1901	Western Kentucky Mining Company	1906	Leander White, Trumbo	70
1904	Big Five Mining Company ..	1906	Blake Terry	71

CRITTENDEN COUNTY—Continued.

No.	Name of Mine.	Location.	Operator.	Title.
72	Lewis Brothers prosp.	4½ m. S. W. of Crayneville	Press Sisco	F
73	Love Calc (E. F.) prosp.	9½ m. N. of Marion.	Lee Cook	F
74	Loveless prosp.	7 m. S. W. of Crayneville	Eagle Fluorspar Company	L
75	Lowery prosps (W. S.)	9 m. S. W. of Marion	C. & A. T. Pope	MR
76	Lucile mines	½ m. S. W. of Marion depot	Lucile Mining Com- pany	L
77	Lucky Star mines...	6 m. S. W. of Marion	C. & A. T. Pope	F
78	Miller mine	6 m. S. W. of Marion	Manley Brothers...	F
79	Mann mine	15 m. W. of Marion.	American Lead, Zinc & Fluorspar Com- pany	L
80	Mary Franklin shaft	5½ m. S. W. of Mar- ion	Mary Franklin	F
81	Matthews shafts....	8¼ m. S. W. of Mex- ico	Kentucky Mining Company	L
82	Matthews mine	8½ m. S. W. of Mex- ico	Eagle Fluorspar Company	L
83	Mayflower shaft....	9½ m. W. of Marion	Shady Grove Mining Company	L
84	Memphis mines	5 m. N. W. of Marion	Kentucky Fluorspar Company	F
85	Meyers prosps	½ m. S. of Mexico...	The Hopkinsville Mining Company.	L
86	Milliken prosps	9 m. W. N. W. of Marion	Marion Mineral Com- pany	L
87	Moore prosps	7¾ m. N. W. of Mar- ion	Deer Creek Mining Company	F

CRITTENDEN COUNTY—Continued.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1904	Marion Zinc Company.....	1904	.....	72
1903	Ohio Valley Mining Com- pany.....	1903	.....	73
1900	Eagle Fluorspar Company ..	1900	.....	74
1903	W. S. Lowery.....	1903	.....	75
1899	R. B. Bigham.....	1904	Bigham mine.....	76
1900	The Republic Mining Com- pany.....	1906	Includes dike pros; Will La Rue prosps.....	77
1900	The Republic Mining Com- pany.....	1902	Manley mine.....	78
1901	Billy Mann.....	1906	.....	79
1901	The Republic Mining Com- pany.....	1902	.....	80
1903	Kentucky Fluorspar Com- pany.....	1906	John Matthews.....	81
†1898 1900	J. W. Waggoner..... Eagle Fluorspar Company..	1906	S. H. Matthew's land.....	82
1903	Shady Grove Mining Com- pany.....	1903	Jim Croft.....	83
1872	Memphis Lead Mining Com- pany.....	1906	Including Beck, Klondike & Paris.....	84
1900	D. C. Roberts.....	1903	.....	85
1902	Marion Mineral Company...	1902	.....	86
1902	R. M. Reed & others.....	1902	Lacy Moore.....	87

CRITTENDEN COUNTY—Continued.

No.	Name of Mine.	Location.	Operator.	Title.
88	Morning Glory prosp.	3 $\frac{1}{2}$ m. N. E. of Pink- ynevill	Cassidy & Dycus	MR
89	Murphey dike prosp.	5 m. S. W. of Marion	Murphey estate	F
90	Nations prosp.	11 m. N. of Marion	Joel A. Farmer	L
91	Newkirk Shafts	1 m. S. W. of Mexico	Abram Newkirk	F
92	Nine Acres mine	5 m. W. of Marion	Nine Acre Mining Company	L
93	Old Dad mine	9 m. W. N. W. of Marion	Marion Mineral Com- pany	F
94	Old Glory mines	8 m. N. N. W. of Marion	Geo. W. Geuder and others	L
95	Old Jim mines	4 $\frac{1}{2}$ m. W. N. W. of Marion	Blue & Nunn	F
96	Parish mine	3 $\frac{1}{4}$ m. S. W. of Mex- ico	Kentucky & Indiana Mining Company	L
97	Pogue mine	3 $\frac{1}{4}$ m. S. W. of Mexico	Marion Mineral Co.	L
98	Polk prosp.	7 $\frac{1}{2}$ m. S. W. of Cra- ynevill	John Polk	F
99	Polk prosp.	5 $\frac{1}{8}$ m. S. S. E. of Mex- ico	Will Polk	F
100	Redd mine	7 $\frac{3}{4}$ m. S. W. of Cra- ynevill	Kentucky Fluorspar Company	L
101	Red Hill mine	15 m. W. of Marion	Red Hill Mining Co.	MR
102	Reiter mine	6 m. S. W. of Crayne- ville	Mrs. Carrie Reiter	F
103	Riley mine	4 m. N. E. of Pickney- ville 8 $\frac{1}{2}$ m. S. W. of Cra- ynevill	Marion Zinc Com- pany	F
104	Silver Star mine	3 $\frac{1}{2}$ m. S. W. of Pink- neyville	Baldwin & Fowler	L
105	Simpson prosp.	5 m. N. W. of Marion	Blue Heirs	MR
106	Sisco dike prosp.	7 m. S. W. of Marion	? L. H. James	F

CRITTENDEN COUNTY—Continued.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1902	Cassidy & Dycus.....	1904	Julius McKinney.....	88
*1890	Unknown.....	1905	.....	89
1906	Geo. P. Roberts.....	1906	.....	90
1901	Abram Newkirk.....	1906	John I. Tabor land.....	91
†1900	Western Kentucky Mining Company.....	1906	New Jim, including Tom Lanham land.....	92
1902	Marion Mineral Company...	1906	Pleas Miller, Miller heirs, Daisy Zinc mine.....	93
*1899	Postlewaithe & Watkins....	1907	Beard, W. of road.....	94
1900	Blue & Nunn.....	1906	Rice land, Blue & Nunn..	95
1904	Ogden & Curry.....	1906	Arch Oliver.....	96
1902	Marion Mineral Company...	1906	.....	97
1905	Marion Zinc Company.....	1905	.....	98
1900	Western Kentucky Mining Company.....	1900	.....	99
1901	Western Kentucky Mining Company.....	1906	Redd Open Cuts.....	100
1902	Bement & Schwab.....	1906	Dave Vaughn, Bement Shafts	101
†1884-5	C. Reiter.....	1905	.....	102
1901	J. N. Riley.....	1906	Big Dick.....	103
1905	Baldwin & Fowler.....	1905	Newt McKinney.....	104
1903	Blue Heirs.....	1905	.....	105
?1902	W. S. Lowery.....	?1902	.....	106

CRITTENDEN COUNTY—Continued.

No.	Name of Mine.	Location.	Operator.	Title
107	Stephenson prosps (Rush).....	1 m. S.W. of Mexico	C. J. Pierce	F
108	Stevens Tunnels ..	12 m. S. W. of Marion	Western Clay & Mining Company.....	L
109	Struck-it-rich mines	5½ m. W. N. W. of Marion	Mountain Lead & Zinc Company.....	L
110	Sullenger prosp.....	5 m. S. of Tolu	S. S. Sullenger	F
111	Tabb mines.....	1¾ to 2¼ m. S. W. of Mexico	Kentucky Fluorspar Company.....	L
112	Tabor mines.....	2½ m. S.W. of Mexico	Blue Glass Fluorspar Company	L
113	Terry shafts	5½ m. N.W. of Marion	W. P. Terry.....	F
114	Terry prosps.....	7 m. N.W. of Marion	Gus Terry Heirs ...	F
115	Thurman mine.....	5 m. N.W. of Marion	The Crittenden County Lead Zinc & Spar Company.....	F
116	Utley prosps.....	10½ m. S.W. of Marion	C. & A. T. Pope	MR
117	Waddell prosps.....	7½ m. S.W. of Mexico	T. L. Waddell	F
118	Walker dike shaft ..	8½ m. S.W. of Marion	John Walker	F
119	Wallingford prosp....	1½ m. E. N. E. of Marion	W. D. Wallingford..	F
120	Watson, A.H. shafts	9 m. S. W. of Marion	C. & A. T. Pope	F
121	Wheatcroft mine ..	2½ m. S. W. of Mexico.....	Wheatcroft Mineral Company	F
122	Wilson mines.....	5 m. W. N. W. of Marion	R. W. Wilson	F
123	Wolsey prosp.	5 m. S. S. E. of Tolu, and 14 m. N. W. of Marion	S. S. Sullenger	F
124	Yandell mines	8½ m. S. W. of Mexico.	Kentucky Fluorspar Company	L
125	York dike shafts ..	6 m. S. W. of Marion	Heyward York	F

CRITTENDEN COUNTY—Continued.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1904	Marion Zinc Company.....	1905	-----	107
?1902	Western Tube Company...	1906	-----	108
1903	Mountain Lead & Zinc Company.....	1904	Includes Lone Rock shaft	109
1902	S. S. Sullenger.....	1902	-----	110
*1878 1890	Tyrie, Brown & Ward.....	1905	Includes Tom Mabry land, Blue & Marble lease, Wheeler mine, etc; Com- mercial, Stephenson in part -----	111
1900	Eagle Fluorspar Company--	1906	-----	112
*1880	Unknown.....	1904	Bill Terry.....	113
1904	Archer & Delker.....	1904	-----	114
1902	The Crittenden County Lead, Zinc & Spar Company.....	1906	-----	115
1903	J. A. Utley.....	1904	Utley & Mitchell	116
1904	T. L. Waddell	1904	-----	117
1902	?J. A. Farmer & others.....	1902	-----	118
1898	W. D. Wallingford.....	1906	-----	119
†1900	?W. S. Lowery.....	1905	½ A. H. Watson Land ...	120
1903	Wheatcroft Mineral Company	1906	Maxwell land.....	121
1882	R. W. Wilson.....	1906	Crittenden Springs mines..	122
†1903	Golconda Milling & Mining Company.....	1905	-----	123
†1852	Unknown.....	1906	Kentucky No. 2; Kentucky in part -----	124
1902	?Liberty Lead & Zinc Company	1903	-----	125

LIVINGSTON COUNTY

No.	Name of Mine.	Location.	Operator.	Title.
126	Alvis prospa.	10 m. S. W. of Marion	Mrs. Acy Alvis.....	F
127	Babb prosp. (A. C.)	1 m. S. W. of Carrs- ville	A. C. Babb	F
128	Babb mine.....	10 m S. W. of Marion	Eagle Fluorspar Company	MR
129	Barnett Heirs prosp.	At Carrsville.....	Wichita, Kansas par- ties	L
130	Bateman prospa.	8 m. S. E. of Carrs- ville	Bateman Heirs	F
131	Ben Belt prosp.....	11 m. W. of Marion	Marion Zinc Com- pany	L
132	Bill Bailey shaft	12½ m. S. W. of Marion.	Shady Grove Mining Company	L
133	Bonanza mine	8 m. S. E. of Carrs- ville	American Lead, Zinc & Fluorspar Com- pany	L
134	Bradshaw prosp.	4 m. S. E. of Carrs- ville	A. Liken & Others..	F
135	Burns mine.....	4 m. S. E. of Carrs- ville	A. Liken & Others..	F
136	Butler Heirs prosp... 12 m. S. W. of Marion		Eagle Fluorspar Company	MR
137	Coker & Levan prosp.	8 m. N. N. W. of Green's Ferry	Cumberland River Mining Company.	MR
138	Coulter prosp.	1½ m. E. of Gol- conda	Golconda Fluorspar Company	L
139	Donakey shaft.....	8 m. N. of Green's Ferry	Cumberland River Mining Company.	MR
140	Dupont prosp.....	¼ of m. S. W. of Carrsville	Unknown .....	.....
141	Emyrian prospa.....	4½ m. S.E. of Carrs- ville	Mrs. Emyrian	F
142	Evening Star mines.	18 m. S. W. of Mar- ion	Eagle Fluorspar Company	F

LIVINGSTON COUNTY

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1906	W. S. Lowery	1906	.....	126
1908	Ohio Valley Mining Com- pany	1908	.....	127
1899	Eagle Fluorspar Company ..	1900	Raymond Babb, Lizzie Col- lins	128
-----	-----	-----	Dr. J. M. Clemens	129
1880	—— Morris	1908	Carlstedt shaft	180
1908	Marion Zinc Company	1908	.....	181
1904	Shady Grove Mining Com- pany	1904	Lindley land	182
*1874	Unknown	1902	Forman mine	183
*1874	Pinkney Burns	1904	Judge Bradshaw	184
1902	Ratcliffe & Williams	1904	Burn's Reserve, Burn's 8 acres, Ratcliffe shaft	185
1899	Eagle Fluorspar Company ..	1899	.....	186
*1874	Unknown	-----	-----	187
-----	Unknown	1906	.....	188
*1874	Unknown	*1900	.....	189
*1874	Unknown	*1874	.....	140
1902	Albany Mining & Investment Company	1908	Dan Stone	141
1899	Eagle Fluorspar Company ...	1908	Cullen	142

LIVINGSTON COUNTY—Continued.

No.	Name of Mine	Location.	Operator.	Title
143	Ferrell prosp	4 ³ / ₄ m. S. E. of Carrs-ville	Warren Ferrell	F
144	Garrett prosp	5 ¹ / ₂ m. S. E. of Carrs-ville	Mildred Garrett	F
145	Grimes prosps	13 m. S. W. of Marion	C. & A. T. Pope	M R
146	Guill (Aus) mine	11 m. S. W. of Marion	Eagle Fluorspar Company	M R
147	Henry Hodge shafts	4 m. N. E. of Pinkneyville	Henry Hodge	F
148	Hudson Mine	5 m. N. E. of Greens ferry	Eagle Fluorspar Company	M R
149	Jamieson prosp	6 m. S. W. of Carrs-ville	Robert Jamieson	F
150	Johnson prosp	15 ¹ / ₂ m. W. S. W. of Marion	Johnson Brothers	F
151	King prosps	2 ¹ / ₂ m. E. of Golconda	Golconda Fluorspar Company	M R
152	Lindley prosp	12 ¹ / ₂ m S. W. of Marion	The Farmland Mining & Investment Company	L
153	Lola prosps	16 m. W. S. W. of Marion	Bob Champion	F
154	Lowery, (J. S.) prosp	11 m. S. W. of Marion	Robert Montanus	M R
155	Lowery, Tom, prosps	12 m. S. W. of Marion	Tom Lowery	F
156	Martin prosps	4 m. N. E. of Pinkneyville	C. & A. T. Pope	M R
157	McDowell mine	15 m. W. of Marion	Marion Zinc Company	L
158	Moreland, prosp	11 ¹ / ₂ m. N. E. of Pinkneyville	J. R. Moreland	F
159	Morning Star mines	13 m. S. W. of Marion	American Lead, Zinc & Fluorspar Company	L

LIVINGSTON COUNTY—Continued.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1802	Will Wallace and others.....	1804	.....	143
1800	American Lead, Zinc & Fluorspar Company.....	1800	Widow Garrett.....	144
1803	?W. S. Lowery.....	1803	Sam Grimes.....	145
1899	Eagle Fluorspar Company..	1800	Damfino, W. A. Guill.....	146
1875	D. Beck and W. Davis.....	?1808	.....	147
1899	Eagle Fluorspar Company..	1800	.....	148
1800	American Lead, Zinc & Fluorspar Company.....	1804	Oronogo.....	149
1804	Johnson Brothers.....	1804	.....	150
1805	Golconda Fluorspar Company	1805	.....	151
1808	The Farmland Mining & Investment Co.....	1808	.....	152
.....	Unknown.....	.....	Bob Champion.....	153
1800	W. S. Lowery.....	1800	.....	154
1803	?Tom Lowery.....	1808	.....	155
1801	C. & A. T. Pope.....	1801	.....	156
1802	J. A. Clark, etc.....	1804	Samuel Lee shaft.....	157
1804	Delaware Mining Company	1804	.....	158
*1874 1800	Unknown..... American Lead, Zinc & Fluorspar Company.....	1801	Mrs. Cox prosp.....	159

LIVINGSTON COUNTY—Continued.

No.	Name of Mine.	Location.	Operator.	Title.
160	Morse prosps	10 $\frac{1}{2}$ m. S.W. of Marion	Albany Mining & Investment Company	L R
161	Nancy Hanks mine	18 m. S. W. of Marion	Albany Mining & Investment Company	S L
162	Norton Shaft	2 $\frac{1}{4}$ m. E. N. E. of Smithland	Western Clay & Mining Company	F
163	Pierce prosps.....	5 m. N. E. of Greens Ferry	J. A. Pierce.....	F
164	Ramage prosps..	5 m. N. E. of Greens Ferry	H. C. & C. N. Ramage	F
165	Royal mines	$\frac{1}{4}$ m. from Cumberland River; 1 $\frac{1}{2}$ S. W. of Smithland	Royal Lead & Spar Company.....	F
166	Schoolfield-Spees Calcite mine.....	3 $\frac{1}{2}$ m. S. E. of Carrsville	Schoolfield-Spees Mining & Milling Company.....	MR
167	Sutts prosp.....	4 m. S. E. of Carrsville	— Sutts	F
168	Stone prosps.....	4 m. S. E. of Carrsville	?Dan Stone	F
169	Stroud shaft.....	2 $\frac{1}{2}$ m. E. of Golconda	Golconda Fluorspar Company	MR
170	The St. John Mines.	1 $\frac{1}{2}$ m. N. W. Greens Ferry	Cumberland River Mining Company	MR
171	Tisdale shaft.....	8 m. N. E. of Pinkneyville	Western Clay & Mining Company.....	MR
172	White pros.....	2. m. E. of Golconda	White	F
173	Woods mines	4 m. N. E. of Pinkneyville	Western Clay & Mining Company	MR
174	Woods shaft.....	3 $\frac{1}{2}$ m. N. E. of Pinkneyville	Western Clay Mining Company.....	MR
175	Wright shaft.....	1 m. S. W. of Carrsville, and 8 m. N. E. of Golconda.....	Prof. Wright.	F

LIVINGSTON COUNTY—Continued.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1904	Heyward & Morse	1902	C. R. Babb, No. 2.....	160
1900	J. Cox & C. M. Miller.....	1906	.....	161
*1902	Livingston Land & Mining Company	1902	Dun Robinson, Lemon Mill Road prosp.....	162
1902	Pittsburg Mining & Reduction Company.....	1902	.....	163
1900	J. S. Waggoner.....	1905	.....	164
†1868	River Valley Mining Company	1908	Old Silver, River Valley, Owen's Cave mines.....	165
1908	Schoolfield-Spees Mining & Milling Company.....	1906	.....	166
1902	— Sutts.....	1902	.....	167
1906	John Harpending & others..	1906	.....	168
1904	Golconda Flourspar Company	1905	.....	169
*1874	Unknown	1906	.....	170
*1874	M. L. & A. M. Hewlett.....	1874	.....	171
1904	Golconda Flourspar Company	1904	.....	172
1874	M. L. & A. M. Hewlett.....	1901	Henry Woods, Hewlett ..	173
*1874	M. L. & A. M. Hewlett.....	*1874	Robert Woods	174
1908	Ohio Valley Mining Company	1904	Prof. Wright.....	175

CALDWELL COUNTY

No.	Name of Mine.	Location.	Operator.	Title.
176	Bright mine	4 m. N. N. E. of White Sulphur	Groom & King	L
177	Byrd prosps.	1 $\frac{1}{4}$ m. E. of Fredonia	C. N. Byrd	F
178	Coleman shafts	4 m. N. W. of Princeton	E. Young Lead, Zinc & Fluorspar Company	F
179	Dodds mines	4 $\frac{1}{4}$ m. N. E. of Princeton	The Union Central Mining Company	L
180	Dunning shafts	5 m. N. W. of Princeton	Princeton Lead & Zinc Company	F
181	Friendship prosps.	5 m. S. of Claxton .....	.....	.....
182	Hopper prosp.	5 $\frac{1}{2}$ m. N. E. of Cobb	Hopper	F
183	Lindsey prosps.	4 m. E. S. E. of Claxton	Dollar and others	F
184	Lowery mine	2 m. E. of Fredonia	Marion Zinc Co.	L
185	Marble mines	4 m. E. of Fredonia & 8 $\frac{1}{2}$ m. N. of Crider	Wm. Marble	F
186	Maxwell prosps.	1 $\frac{1}{2}$ m. E. of Fredonia	Milton Maxwell	F
187	Ray mine	2 m. E. of Fredonia	Marion Zinc Company	L
188	Satterfield prosp.	3 $\frac{1}{2}$ m. S. S. W. of Princeton	Satterfield	F
189	Senator mines	4 m. N. W. of Princeton	Senator Mining Company	F
190	Stone mine	3 $\frac{1}{4}$ m. N. E. of Crider	The Union Central Mining Company	L
191	Tyrie mine	3 m. N. of Princeton	John W. Holliwell	L
192	Wigginton prosp.	1 m. E. of Fredonia	Dick Wigginton	F
193	Williamson prosp.	3 $\frac{3}{4}$ m. N. E. of Crider	The Union Central Mining Company	F
194	Williamson, J. W. shaft	4 m. N. E. of White Sulphur, 5 m. N. E. of Crider	J. W. Williamson	F

CALDWELL COUNTY.

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
†1903	Groom & King	1904	.....	176
1903	J. McGraw	1903	.....	177
1902	E. Young Lead, Zinc & Fluorspar Company	1904	.....	178
1901	The Union Central Mining Company	1905	.....	179
1902	Princeton Lead & Zinc Company	1903	.....	180
.....	.....	.....	.....	181
1903	Unknown	1903	.....	182
1903	Dollar and others	1903	.....	183
.....	Marion Zinc Company	?1904	.....	184
*1875	Sumner Marble & Son.	1906	.....	185
1903	Fredonia parties	1904	.....	186
1902	Marion Zinc Company	?1905	.....	187
1902	?Newkirk	1902	.....	188
1902	Senator Mining Company ..	1904	Scacyfat, Sheridan, Bodard Springs, Morse	189
1901	The Union Central Mining Company	1906	.....	190
1902	J. W. Holliwell	?1904	.....	191
1903	Dick Wigginton	1903	.....	192
1902	The Union Central Mining Company	1902	.....	193
1903	?J. W. Williamson	?1903	.....	194

CHRISTIAN COUNTY

No.	Name of Mine.	Location.	Operator.	Title.
195	Ellis prosp.....	5 ¹ / ₄ m. N. E. of Hop- kinsville	Ellis	F
196	Freeman shaft.....	5 ¹ / ₂ m. N. E. of Hop- kinsville	W. G. Head.....	L
197	Fruit Calc prosp....	7 m. N. E. of Hop- kinsville	Capt. Fruit.....	F
198	Head's Victoria mines (prosp.).....	4 m. W. of Crofton..	W. G. Head.....	L
199	Hord prosps.....	4 ³ / ₄ m. N. N. E. of Hopkinsville	Giles Creek Mining Company.....	L
200	Jarvin prosp.....	6 m. N. E. of Hop- kinsville	W. G. Head.....	L
201	McReynolds prosp...	10 m. W. N. W. of Crofton.....	McReynolds.....	F
202	Williams prosp.....	2 ¹ / ₂ m. N. of Hop- kinsville	L. G. Williams....	F

LYON COUNTY

203	Cook Calc prosp....	3 m. S. E. of Eddy- ville.....	Mrs. Eliza Cook....	F
204	Eddyville Calc prosp.	At Eddyville Land- ing.....	Unknown	
205	Padon prosp.....	8 ¹ / ₂ m. S. W. of Mex- ico	Kentucky Mining Company of Ariz..	L
206	Redd manganese prosp	3 m. S. W. of Dula- ney	Jesse Redd (col) ...	F
207	Smith prosps	4 m. S. of Grand Rivers.....	Charlie Smith (col)	F
208	Wadlington prosp...	4 ¹ / ₂ m. S. of Fre- donia	Loyd Wadlington...	F

CHRISTIAN COUNTY

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1903	Ellis	1903	.....	195
1903	W. G. Head	1906	Head prosp.	196
1904	Williams and others	1904	.....	197
1903	W. G. Head .....	.....	.....	198
1903	Giles Creek Mining Com- pany	1903	.....	199
1903	R. Bolling	1903	Bolling prosp.	200
1906	McReynolds	1906	.....	201
1903	L. G. Williams	1903	.....	202

LYON COUNTY

.....	.....	*1905	.....	203
†1904	Unknown	†1904	.....	204
1905	Kentucky Mining Company of Ariz.	1905	.....	205
1904	Unknown	1905	.....	206
*1904	Unknown	1904	.....	207
*1905	Loyd Wadlington	1905	Capt. Stone, Stonehurst...	208

TRIGG COUNTY

No.	Name of Mine.	Location.	Operator.	Title.
209	Cooper prosp.....	1 m. E. of mouth of Little River.....	Ed. Cooper.....	F
210	Hillman prosp.....	$\frac{1}{2}$ m. E. of mouth of Little River.....	Widow Hilman.....	F
211	Ferguson Spring prosp.....	$8\frac{1}{2}$ m. S. S. W. of Rock Castle.....	Widow Hilman.....	F
212	Johnson prosp.....	At mouth of Little River.....	Lee Johnson.....	F
213	Malone prosp.....	3 m. N. W. of Gracey.....	Gracey Mining Company.....	L
214	O'Hara shaft.....	$3\frac{1}{4}$ m. N. N. W. of Gracey.....	Unknown.....	L
215	Overby shafts.....	3 m. N. N. W. of Gracey.....	Gracey Mining Company.....	F
216	Owen's shaft.....	3 m. N. N. W. of Gracey.....	Unknown.....	F
217	Peel prosp.....	1 m. E. of mouth of Little River.....	Q. Peel.....	F
218	Pue prosp.....	1 to 2 m. S. W. of mouth of Little River.....	Jim Pue.....	F
219	Taoler shafts.....	$8\frac{1}{2}$ m. N. N. W. of Gracey.....	Charles Haury.....	L

UNION COUNTY.

220	Baryta Spring prosp.	3 m. N. N. W. of Henshaw.....	Tom Young.....	F
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WEBSTER COUNTY.

221	Dixon prosp.....	$1\frac{1}{2}$ m. from Dixon, at Bald Knob....	Hardwick & Henson	F
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TRIGG COUNTY

OPERATIONS.			SYNONYMS.	No.
First Date.	By Whom.	Last Date.		
1904	Ed. Cooper.....	1904	209
1904	Hillman Brothers.....	1904	George Pool prosp.....	210
	.....		.....	211
	.....		.....	212
1904	Gracey Mining Company...	1904	.....	213
1904	Unknown.....	1904	.....	214
1904	Gracey Mining Company...	1904	Gracey mine.....	215
1904	Owens, for others.....	1904	Boynton prosp.....	216
1904	Q. Peel.....	1904	217
	218
1904	The Buffalo Mining Co.....	1905	Buffalo mine.....	219

UNION COUNTY.

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WEBSTER COUNTY.

1902	1902	221
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CONCENTRATING AND GRINDING PLANTS.

PRESENT MILLS.

No.	Name.	Location.	Erect- ed.	Operator.	Character, Equipment.	Problem.	No.
1	Columbia	At Columbia mines, 5 m. W. of Marion.	1902	Columbia Mining Co.	Self feed hopper, trommel, 8 Cooley jigs, 2 Overstrom tables; products re-jigged automatically. 30 tons.	To make zinc & lead heads; quartzite limestone, calcite, fluorspar tails.	1
2	Evening Star	At Evening Star mine, 18 m. S. W. of Marion.	1904	Eagle Fluorspar Co.	2 crushers, rotary dryer, 4 sets rolls, 4 screens, Hooper Pneumatic tables, etc.; dry separation. Capacity unknown.	To make zinc & lead heads; fluorspar & jasperoid tails; ore fine-grained.	2
3	Kentucky	At Marion 1 M. S. of depot. E. of I. C. R. R.	1899	Kentucky Fluorspar Co.	Concentrating: Crusher, trommel, 2 sets rolls, 2 Cooley jigs; 30 T. Grinding: Direct fired flat dryer, conveyors, 2 buhrmills, bins, barrel settlers; 20 T.	To make lead & fluorspar heads; calcite, limestone, etc. tails. To make ground fluorspar.	3
4	Nancy Hanks	At Nancy Hanks mine, 18 m. S. W. of Marion.	1905	Albany Mining & Investment Co.	Concentrating: Self feed hopper, crusher, 8 sets rolls, 8 Cooley jigs, Ratcliffe-Cohenour screen; 30 T. Grinding: Buhr mill, tube mill, flat direct dryer; 15-20 T. Power: 100 h. p. tubular boiler, 60 h. p. engine.	To make lead and fluorspar heads; calcite and limestone tails. To grind fluorspar.	4
5	Nine Acre	At Nine Acre mine, 5½ m. W. of Marion.	1905	Nine Acre Mining Co.	Old mill: Crusher, rolls, hand jigs 3. Being remodeled with machine jigs, tables and Sanders separator.	To make lead & zinc heads; fluorspar, calcite, limestone, etc., tails.	5

CONTINUED, CONCENTRATING AND GRINDING PLANTS.
PRESENT MILLS.

No.	Name.	Location.	Erect- ed.	Operator.	Character, Equipment.	Problem.	No.
6	Old Dad	At Old Dad mine, 5½ m. W. of Marion.	1905	Marion Mineral Co.	2 log washers, 2 Overstrom tables. Power: 14 h. p. engine, 60 h. p. boiler.	To clean zinc carbonate from sand, etc.	6
7	Riley	At Riley mine, 18 m. S. W. of Marion.	1903	Marion Zinc Co.	Log washer, self feed hopper, (3) Faust and (1) Cooley jigs, crusher, 8 sets rolls, 2 trommels, shaking screen, settling tanks, etc. Power: (1) 100 h. p. and (1) 80 h. p. boiler; (1) 80 h. p. engine. Grinding: Section to be installed.	To make fluor-spar & lead heads; calcite, quartzite, limestone, barite, etc., tails.	7
8	Sanders	½ m. S. of depot at Marion.	1905	Sanders Ore Separating Co.	Crusher, rolls, screens, tables, Sanders flotation separators. Power: 80 h. p. boiler and about 60 h. p. engine.	To make zinc and lead heads; fluor-spar and remainder tails.	8
9	Temme	8½ m. S. of Tolu, at Dalton prosps.	1904	Temme & Others.	Cylindrical washer, Overstrom tables, hydraulic classifier. Not operating.	To separate chert, sand, and red clay from zinc carbonate.	9
10	Union Central	8 m N. W. of Crider.	1906	Union Central Mining Co.	Self feed hopper, crusher rolls, spitzkasten, 2 Cooley jigs, etc. Power: (2) 100 h. p. boilers and 75 h. p. engine.	To separate lead and fluor-spar, calcspar, limestone, etc., tails.	10

Dismantled Plants.

At the Big Four mine (adjoining LaRue shaft) a hand-jigging plant was used for a time. A hand-jig was also used at the Lucile mine, but without success. The National mill at the Marble mines was a Joplin type plant, but was not very successful, owing to abundance of zinc blende. The Old Jim mill was removed to the Old Dad. The Seacoast mill was a dry process mill for the separation of zinc and fluorspar erected at Paducah, making use of Krom air jigs, but was a failure and has been removed to Madison, Ind. The Columbia and Royal mines had mills for separating fluorspar and lead which have long been dismantled, or out of use.

Present Operators and Holders of Mining Lands.

One hundred and eight operators and property holders previously operated in the Western Kentucky spar, lead and zinc district that are no longer in the business. One hundred and seventy-seven hold property or operate at present, including most of the property once held by the previous operators. Of these, there are 82 individuals, 44 firms and 5 corporations. The incorporated operators represent a capitalization of about seven million dollars. Over half have Kentucky charters, and remainder from scattered States. A list is here presented of the present operators and holders of mining lands with a list of their officers, properties, etc. A number following the name of a property is the number given it in the foregoing tables where details of location, history, synonymous names, are to be found. Those not so numbered have either not been prospected or, if so, not successfully as yet.

Royalties.—Properties are held by the companies either in fee, mineral right, lease or sub-lease. The royalties paid vary widely, depending on, (1) The year the lease was taken, hence older leases have a much lower royalty; (2) Distance from railroad; and (3) Character of wagon road over which haul must be made. The royalties paid per ton vary thus: Fluorspar, 10 to 75 cents. Barite,

10 to 50 cents. Lead and zinc concentrates, from 25 cents to \$2.50, but occasionally 10 per cent. of the market value. Firesand, 15 cents. They vary from one to ninety-nine years in length. A few of the leases have monthly rental clauses whereby the land is paid for in installmnts, the land being under lease from year to year till paid for, the lease being forfeited upon non-payment of rent. Many of the leases have simple option clauses.

1. Albany Mining & Investment Co., Inc. West Virginia charter, March 26, 1902. Capital \$1000,000. Main office, Albany, Ind.; branch, Salem, Ky.
Officers, Directors: Pres., A. L. Stephenson, Findlay, O.; V. Pres., W. N. Russell, Dunkirk, Ind.; Sec., L. W. Tucker; Treas., J. M. Wilhite, of Albany, Ind.; Supt., and Gen. Mgr., Walter L. Vera, Salem, Ky.; Elmer Stephenson, J. B. Clark, A. P. Duncan, Wm. Marks, Chas. Austin, Henry Batch. Annual election: July 14.
Properties in Crittenden county.
Butler, John (21).
Properties in Livingston county.
Babb, C. R. Babb (home place), (160), Nancy Hanks, (161), Nancy Hanks mill.
2. Alice Mining Co. Office: Marion, Ky. Gen. Mgr., M. Schwab.
Property in Crittenden county.
Belt, J. O., (2).
3. Alvis, Mrs. Acy. Office: Salem, Ky.
Property in Livingston county.
Alvis, (126).
4. American Lead, Zinc & Fluorspar Co., Inc. Arizona charter, 1900. Capital \$100,000. Stockholders, 3. Office: Cleveland, O.
Officers, Directors: Pres., T. J. Charlesworth, V. Pres., Ed. Langenbach, care Berger Mfg. Co.; Sec., C. W. Laird; Treas., Henry W. Gazzell, Cleveland, O.; A. J. Morton, R. T. Langenbach

Properties in Livingston county.

Bonanza, (133)

Morning Star, (159).

Nancy Hanks, (161); sub-leases to Albany Mining & Investment Co.

Mitchell, L. P.—L.

Mann, W. H.—L. In litigation. (79).

5. Babb, A. C. Office: Marion, Ky.

Property in Livingston county.

Babb, A. C. (127).

6. Baldwin & Fowler. 1905. Partners: James Baldwin, Koon, Ky.; Otho Fowler, Kuttawa, Ky. Office: Kuttawa, Ky. Supt., James Baldwin.

Property in Livingston county.

McKinney, Newt., (104).

7. Barger, D. B. Office: Fordsferry, Ky

Property in Crittenden county.

Barger, D. B. (6).

8. Bateman Heirs. Office: Lola, Ky. Agt., John Bateman.

Property: Livingston county:

Bateman Heirs. (130).

9. Beard, P. E. Office: Fordsferry, Ky.

Property in Crittenden county.

Beard, P. E. (8).

10. Beard Heirs. Cordelia Beard and others. Office: Fordsferry, Ky.

Property in Crittenden county.

Beard Heirs. (9).

11. Belt, Asa. Office: Marion, Ky.

Property in Crittenden county.

Belt, Asa. (10).

12. Big Four Mining & Development Co. 1904. Office: Morganfield, Ky. Gen. Mgr., A. D. Noe, Morganfield, Ky.

13. Big Four Mining, Milling & Development Co., Inc. November, 1903. Capital \$150,000. Main office, Muncie, Ind.; branch, Marion, Ky.

Officers, Directors: Pres., Jerre Garrard; V. Pres., J. H. Leffler; Sec., James M. Motsenbocke; Treas., Ralph A. Clark, E. L. Lewis, Joe G. Leffler, Ray Hickok, A. S. Botkin, D. L. Peck. Annual election, first Monday in November.

Property in Crittenden county.

G. W. & J. A. Corn, 95A., (15).

Big Four Mine. (16).

14. Bloomfield, Loyd. Office: Paducah, Ky. Holds some leases in Western Kentucky.

15. Blue, J. W., Jr. Office: Marion, Ky.

Property in Crittenden county.

Nesbitt—244 A.—F.

Robertson—25 A.—F.

16. Blue & Nunn. Partners: J. W. Blue, Jr., and C. S. Nunn, Marion, Ky. 1899. Office: Marion, Ky.

Property in Crittenden county.

Nine Acres—9 A.—F. }

Tom Lanham, 148 A.—F. }

Old Jim—660 A. (95).

Ryan—5-6 of 46 A.—F.

(92), Leased to Nine Acres Min. Co.

17. Blue Grass Fluorspar Co., Inc. West Virginia charter, November 9, 1906. Capital \$25,000. Shares, 2,500. Offices: Main, St. Paul, Minn.; branch, Marion, Ky.

Officers: Pres., G. J. Lovell, St. Paul, Minn.; V. Pres. & Gen. Mgr., T. H. B. Haase, Marion, Ky.; Sec. & Treas., R. C. Haase, St. Paul, Minn.

Directors: G. J. Lovell, E. A. Whitaker, J. N. Storr, R. C. Haase, H. M. Lewis.

Property in Crittenden county.

Asbridge, (4).

Tabor, (112).

18. Blue Heirs. Agt., J. W. Blue, Jr. Office: Marion, Ky.

Properties in Crittenden county.

Allen, R. M.—42 A. & MR.

Blue Heirs, 100 A.—F.

Blue Heirs, 48 A. —MR.

Blue Heirs, 11 $\frac{3}{4}$ A. (17).

Maynard, 108 A.—MR.

Simpson, 59 A. (105).

19. Butler, Albert. Office: Salem, Ky.
Property in Crittenden county.
Butler, A., 250 A.; in a prospect located on a fault, traces of lead and fluorspar are reported to have been found on this property.
20. Byrd, C. N. Office: Fredonia, Ky.
Property: In Caldwell county:
Byrd, C. N. (177).
21. Campbell, T. C. Office: Dycusburg, Ky.
Property in Crittenden county.
Campbell, T. C.
22. Campbell Mining Co., Inc. New Jersey charter, Nov. 1904. Capital \$100,000. Office: Louisville, Ky.
Officers, Directors: Pres., Wm. Miller, Louisville, Ky.; V. Pres., L. A. Campbell, Louisville, Ky.; Sec., ——— Whitehouse, Louisville, Ky.; Treas., L. A. Campbell, Louisville, Ky.; Supt., J. M. Persons, Marion, Ky.
Property in Crittenden county.
Pogue, R. M., F.
23. Cardin, A. H. Office: View, Ky.
Property in Crittenden county.
Cardin, A. H. 1,000 A., (22).
24. Cassidy & Dycus. 1903. Partners: S. H. Cassidy and F. G. Dycus. Office: Dycusburg, Ky.
Property in Crittenden county.
Morning Glory Prospect. (88).
Property near Caldwell Springs.
25. Champion, Bob. Office: Lola, Ky.
Property in Livingston county.
Champion, Bob.
26. Champion, Widow. Office: ? Salem, Ky.
Property in Crittenden county.
Champion, Widow. (24).
27. Clark, W. H. Office: Lola, Ky.
Property in Crittenden county.
Clark, W. H. (25).

28. Clemens, Dr. J. N. Office: Carrsville, Ky.
Property in Livingston county.
Barnett heirs: Leased to Witchita, Kan., parties. (129).
29. Clemens, W. P. Office: Resort, Ill.
Property in Crittenden county.
Clemens, W. P. (26).
30. Clement, F. M. Office: View, Ky.
Property in Crittenden county.
Clement, F. M. Tract near View.
Clement mine. (27).
31. Columbia Mining Co., Inc. Kentucky charter, June 30, 1902. Capital \$100,000. Shares, 1,000. Office: Marion, Ky.
Officers: Pres., Thos. D. Jones, Chicago, Ill.; V. Pres., R. W. Bingham, Louisville, Ky.; Sec. & Treas., W. C. Johnson, Paris, Tenn.
Directors: Thos. D. Jones, R. W. Bingham, J. C. Porter, N. H. Snow.
Property in Crittenden county.
Columbia Mines. (28). See No. 178 for company sub-leasing.
32. Commodore Mining Co., Inc. Kentucky charter, November 19, 1904. Capital \$200,000. Shares, 2,000. Office: Louisville, Ky.
Officers, Directors: Pres., Wm. Miller, Louisville, Ky.; V. Pres., John Sheas, Louisville, Ky.; Sec. & Treas., C. H. Whitehouse, Louisville, Ky.; Supt., J. M. Persons, Marion, Ky.
Properties in Crittenden county.
Commodore. (129).
Flanary, R. M.—MR. Syn.: Blue Heirs.
33. Cook, Lee. Office: Fordsferry, Ky.
Property in Crittenden county.
Love, E. F. (73).
34. Cooper, Ed. Office: Trigg Furnace, Ky.
Property: In Trigg county:
Cooper, Ed. (209).
35. Cox, Felix G. Office: Marion, Ky.
Property in Crittenden county.
Cox, Felix G. (30).

36. Crider, Geo. M., and others. 1904. Partners: Geo. M. Crider, C. J. Haury, Marion, Ky., and Charles Haury, Oakland City, Ind.
Property in Crittenden county.
Bertha May Mine. (13).
37. Crittenden County Lead, Zinc & Spar Co., Inc. South Dakota charter, July, 1902. Capital \$10,000. Offices: Pierre, S. D., and Marion, Ky.
Officers, Directors: Pres., Isaac Reese, Memphis, Tenn.; V. Pres., A. C. Moore, Marion, Ky.; Sec.-Treas.-Gen.Mgr., John A. Moore, Marion, Ky. Ira E. Ellis.
Property in Crittenden county.
Thurman, (115).
38. Cumberland River Mining Co., Inc. ?Pennsylvania charter, 1906. Capital \$300,000. Shares, 3,000. \$50,000 paid up; \$250,000 treasury stock. Offices: Main, Pittsburg, Pa.; branch, Salem, Ky.
Officers: Pres., Anthony Schwab; V. Pres., R. V. Rovi-
anck; Sec. & Treas., R. H. Marshall, all of Pittsburg,
Pa.; Supt., D. Woolford, Salem, Ky.
Directors: J. W. Grier, W. K. McGinness, Anthony
Schwab, P. V. Rovi-
anck.
Properties in Livingston county.
Coker, 100 A., (137).
Donakey, 100 A., (139).
Vincentheller, 53 A. MR.
The St. John Mines. (170).
39. Daugherty, Louis. Office: Fordsferry, Ky.
Property in Crittenden county.
Daugherty, L. (35).
40. Davenport Brothers. Office: View, Ky.
Property in Crittenden county.
Davenport Brothers. (37).
41. Dean & Wilson. Office: Marion, Ky.
Property in Crittenden county.
Dean & Wilson. (38).

42. Deer Creek Mining Co., Inc. Kentucky charter, October 26, 1903. Capital \$10,000.

Officers, Directors: Pres., J. M. Crowe, Morganfield, Ky.; V. Pres., Wm. Barnett, Tolu, Ky.; Sec. & Treas., J. L. Harris, Morganfield, Ky.; Gen. Mgr., C. W. Cartwright, Sheridan, Ky. A. D. Noe, J. A. Sutton.

Properties in Crittenden county.

Deer Creek Mine. (39).

Lacy Moore prosp. (87).

43. Dollar and Others. Partners: J. B. Kevil and J. G. Dollar, of Princeton, Ky., J. A. Dollar, of Marion, Ky. Office: Care J. A. Dollar, Marion, Ky.

Property in Caldwell county.

Lindsey. (183).

44. Dollar, McFee & Baker, Partners: J. A. Dollar, J. A. Baker, E. M. McFee, of Marion, Ky. Office: Marion, Ky.

Property in Crittenden county.

Franklin, E. L. (47).

45. Eagle Fluorspar Co., Inc. West Virginia charter, October, 1898. Authorized capital \$200,000. Shares, 2,000. Issued common shares, \$79,500; preferred, \$45,000. Stockholders, 11. Offices: Main, 1321 Main Street, Wheeling, W. Va.; branch, Salem, Ky.

Officers: Pres., Gen. Mgr., Consult, Eng., D. Garth Hearne, Sec.-Treas., R. A. McCabe, of Wheeling W. Va.; Supt., J. A. Cohenour, Salem, Ky.

Directors: R. A. McCabe, L. E. Sands, E. L. Wiles, Geo. W. Woods, D. Garth Hearne.

Properties in Livingston county.

Babb, C. R., (128).

Butler Heirs. (136).

Cullen. (142).

Guill, W. Austin. (148).

Hudson, J. K. P. (148).

Hodge, Willis,—F. to Coal.

Sills, J. B.,—F. to Coal.

Properties in Crittenden county.

Dan Riley. (33).
Howard, H. G. (59).
Loveless, D. C. (74).
Matthews, S. H. (82).
Pace, John G. (MR).
Watson, A. H., North half, MR.

46. Eclipse Mining Co., Inc. 1905. Offices: Louisville, Ky., and Marion, Ky.

Officers: Pres., Theodore Klarer; Sec.-Treas., Henry A. J. Puls; Gen. Mgr., F. W. Kaiser, of Louisville, Ky.; Supt., R. D. Drescher, Marion, Ky.

Property in Crittenden county.

Eclipse Mine. (42).

47. Edwards Mining Co., Inc. Kentucky charter, 1905. Capital \$100,000. Offices: Main, Kentucky Title Bldg., Louisville, Ky.; branch, Marion, Ky.

Officers: Pres., James P. Edwards; V. Pres., Wm. F. Tafel; Sec., Gen'l Mgr., A. E. Detwieler; Treas. Walter N. Young of Louisville, Ky.; Supt. H. O. Radcliffe; Consult. Eng., John L. Harpending of Crittenden Springs, per Marion, Ky.

Directors: J. P. Edwards, W. Miller, A. E. Detwieler, J. M. Rankin and Walter Young, Louisville, Ky.

Property in Crittenden county.

Woods tract, 46 A., (43).

48. Ellis, Lee.

Office: Per Ellis Ice Co., Hopkinsville, Ky.

Property in Christian county.

Ellis, (195).

49. Emyrian, Mrs. Office: Carrsville, Ky.

Property in Livingston county.

Emyrian, Mrs., (141).

50. Evansville Lead, Zinc & Spar Co., Incorporated. Ind. charter May 9, 1902. Capital \$5,000. Office: Evansville, Ind.

Officers, Directors: Pres., Louis A. Daus, Evansville, Ind.; V. Pres. J. Wm. Glichman; Sec.-Treas. J. H. Rosenberger, per Am. Pharmacal Co., Evansville, Ind.; O. A. Carlstedt.

Property in Livingston county.

John T. Bradshaw, F. Dug Hardin.

51. E. Young Lead, Zinc & Spar Mining Co., Inc. Kentucky charter, Sept. 6, 1902. Capital \$30,000. Office Princeton, Ky.

Officers: Pres. E. Young; V. Pres. J. F. Ingram; Sec. C. M. Wood; Treas. Jno. R. Wylie of Princeton, Ky. Directors: E. Young, J. F. Ingram, M. J. Groom, J. R. Wylie, J. G. Orr.

Property in Caldwell county.

Wm. Coleman, (178).

52. Farmer, James. Office: Marion, Ky.

Property in Crittenden county.

Farmer, J. (44).

53. Farmer, Joel A. Office: Marion Ky.

Property in Crittenden county.

Nations, (90).

54. Farrell, Warren. Office: Carrville, Ky.

Property in Livingston county.

Ferrell, W., (143).

55. Franklin, E. B. Office: Levias, Ky.

Property in Crittenden county.

Franklin, E. B., (47).

56. Franklin, Mrs. Mary. Office: Levias, Ky.

Property in Crittenden county.

Franklin, Mrs. Mary, (80).

57. Fruit, Capt. Office: Hopkinsville, Ky.

Property in Christian county.

Fruit, Capt., (197).

58. Garrett, Mrs. Mildred. Office: Lola, Ky.

Property in Crittenden county.

Garrett, Mrs. M., (144).

59. Geuder and Others. 1901. Office: Care M. E. Fohs, Marion, Ky.

Property in Crittenden county.

Old Glory Mines, (94).

60. Giles Creek Mining Co., incorporated 1903. Office: Care C. O. Prowse, Hopkinsville, Ky. Directors: John P. Prowse, W. T. Fowler, C. O. Prowse, E. T. Cook, Jack Tate, of Hopkinsville, Ky.
Property in Christian County.
Hord, L., (199).
- 61.* Givens Mining Co., Inc. Kentucky charter, February 10, 1904. Capital, \$100,000. Shares, 1,000. Offices: Marion and Providence, Ky.
Officers, Directors: Pres.-Gen. Mgr., Ross Givens, Providence, Ky.; Sec.-Treas., C. L. Hinkle and B. H. Roney, of Evansville, Ind.
Property in Crittenden county.
Corn, (48).
? Croft, J., L.
62. Glendale Mining Co., Inc. Kentucky charter, October 1, 1903. Capital, \$12,000. Shares, 120. Office: Morganfield, Ky.
Officers, Directors: Pres., T. M. Dyer; V. Pres., W. T. Drury; Sec.-Treas., G. L. Drury, J. M. Crowe, S. C. Anderson, S. L. Clenents, of Morganfield, Ky. All are directors except V. Pres. Property in Crittenden county.
Austin, H., (49). Leased to J. M. Persons.
63. Golconda Fluorspar Co., Inc., 1906. Office: Louisville, Ky. Capital, \$50,000. Officers: Geo. G. Fetter, care of Geo. G. Fetter Co., Louisville, Ky. Directing Eng., J. E. Wright, Louisville, Ky.
Property in Livingston county.
Coulter, R. E., (138).
King, W. R., (151).
Stroud, G. W., (169).
64. Gracy Mining Co., Inc. District of Columbia charter, 1903. Capital, \$600,000. Shares, 600,000. Office: Gracy, Ky. Officers, Directors: Pres., Thos. S. Shaw, Cadiz, Ky.; V. Pres., Gipp Watkins, Gracy, Ky.; Sec., J. T. Wall, Hopkinsville, Ky.; Treas., Dr. Darwin Bell, Gracy, Ky.; B. J. Wall, R. T. Stowe, Lewis Weston, Chas. Cox, G. H. Medley, G. H. Stowe, G. Breathitt, H. T. Watkins, Harry Gaines.

Property in Trigg county.

Cox, Chas., 18½ A., L.

Gaines, P., L.

Kirby, E. L., 27 A., L. (3 tracts).

Kirby, Wm., 319 A., L. (2 tracts).

Malone, H. F., 188 A., (213).

Overby, 2 A., (215).

65. Grassham and Others. 1902. Partners: C. C. Grassham, Paducah, Ky.; J. D. Clopton, Smithland, Ky.; Bird Clemens, and Quade. Office: Smithland, Ky., care of J. D. Clopton.

Property in Livingston county.

Mantz Spring Prosp. (J. A. Thompson tract). Prosp. is 50 feet west of fault; a little pyrite in shale.

66. Gray, Mrs. Office: Irma, Ky.

Property in Crittenden county.

Gray, Mrs., (50).

67. Green, Daniel J. Office: Fordsferry, Ky.

Property in Crittenden county.

Green, D. J., (51).

- 68.* Groom & King. 1903. Partners: Major Groom and ——— King. Office: Princeton, Ky.

Property in Caldwell county.

† Bright, Green, (176).

69. Hard, A. Office: Marion, Ky.

Property in Crittenden county.

Hard, A., (53).

70. Hardwick & Henson. 1902. Partners: W. C. Hardwick and J. M. Henson.

Property in Webster county.

Hardwick & Henson, (221).

71. Harpending and Others. 1904. Partners: J. L. Harpending, Crittenden Springs, Ky.; Sam Gugenheim, C. J. Pierce, D. C. Porter, of Marion, Ky. Office: Crittenden Springs, Ky.

Properties in Crittenden county.

Belt-Sullenger, (11).

Ed Flanary, L.

72. Harpending and Others. 1906. Partners: J. L. Harpending, Crittenden Springs, Ky.; Wm. Miller, Louisville, Ky., and another. Office: Crittenden Springs, Ky.
Properties in Crittenden county.
Bryant, C. W., (19).
73. Harpending & Miller. 1906. Partners: J. L. Harpending, Crittenden Springs, Ky.; Wm. Miller, Louisville, Ky.
Properties in Crittenden county.
Flanary, R. E., O., (46).
Turner, Spring., O.
74. Haury, Charles. 1903. Office: Oakland City, Ind.
Property in Trigg county.
Taoler, (219).
75. Head, W. G. 1903. Office: Madisonville, Ky.
Properties in Christian county.
Bolling, R., (198).
Freeman, (196).
Jarvin, (200).
76. Heath, S. M. Office: Fordsferry, Ky.
Property in Crittenden county.
Shanks Place, F.
77. Henry, James. Office: Marion, Ky.
Properties in Crittenden county.
Bibb, G. R., (14).
Stephenson, J. E., L.
Stephenson, ———, L.
78. Hillman, Widow. Office: Trigg Furnace, Ky.
Properties.
Ferguson Spr., (211).
Pool, G., (210).
79. Hodge, Henry. Office: Salem, Ky.
Property in Livingston county.
Hodge, H., (147).
80. Hollowell, John W. Office: Princeton, Ky.
Property in Caldwell county.
Tyrie, (191).

81. James, L. H. Office: Marion, Ky.
Property in Crittenden county.
Sisco, (106).
82. Jamieson, Robert. Office: Lola, Ky.
Property in Livingston county.
Jamieson, R., (149).
83. Johnson, Lee. Office: † Canton, Ky.
Property in Trigg county.
Johnson, L., (212).
84. Johnson Brothers. Office: Lola, Ky.
Property in Livingston county.
Johnson, (150).
85. Jones, Anderson. Office: Sheridan, Ky.
Property in Crittenden county.
Jones, A., (60).
86. Kentucky & Indiana Mining Co., Inc., 1904. Capital,
\$25,000. Offices: Evansville, Ind., and Francis, Ky.
Officers: Pres., Leon Curry, Evansville, Ind.; V. Pres.-
Supt., W. A. Oliver, Francis, Ky.; Sec.-Treas., H. H.
Ogden, Evansville, Ind.
Property in Crittenden county.
Parish, (96)
87. Kentucky Fluorspar Co., Inc. Kentucky charter, January
15, 1902. Capital, \$100,000. Shares, 1,000. Stock-
holders, 8. Office: Marion, Ky.
Officers: Pres.-Supt., C. S. Nunn; V. Pres., J. W. Blue.
Jr.; Sec.-Treas.-Gen. Mgr., H. A. Haynes, of Marion,
Ky. Directors: P. S. Maxwell, Nelson H. Snow, J. W.
Blue, Jr.
Properties in Crittenden county.
Blue & Marble, (111).
Brown, (18).
Holly, (58).
Memphis, (84).
Redd, (100).
Tabb, (111).
Yandell, (124).

88. Kentucky Mining Co., Inc., of Kentucky. Kentucky charter, October, 1902. Capital. \$6,000. Office: Louisville, Ky.
Officers, Directors: Pres., Curran Pope; V. Pres., A. Thruston Pope; Sec.-Treas., V. P. Collins; H. A. J. Puls, A. M. Hunter, of Louisville, Ky.
Properties in Crittenden county.
Rutter, F. (3 tracts).
89. *Kentucky Mining Co., Inc., of Arizona. Arizona charter, 1905. Office: Eddyville, Ky.
Officer: Sec.-Gen. Mgr., U. S. King, Eddyville, Ky.
Property in Crittenden county.
Matthews, J., (81).
Property in Lyon county.
Padon, (205).
90. *Keyes & Davis. 1903. Partners: J. O. Keyes, Akron, O., and Walter Davis, Lola, Ky. Office: Care of W. Davis, Lola, Ky.
Property in Crittenden county.
Watson, Henry, (62).
91. Keystone Mineral & Mining Co., Inc. Kentucky charter, April 30, 1904. Capital, \$40,000. Office: Sturgis, Ky.
Officers, Directors: Pres.-Treas., J. D. Hopewell, Sturgis, Ky.; Sec.-Supt., T. E. Hopewell, Marion, Ky.; V. Pres., H. Lee Upton, Louisville, Ky.; W. W. Hopewell, W. H. Wheeler, Sam D. Martin. Annual election, first Tuesday in March.
Property in Crittenden county.
Carter, (63).
92. King, James. Office: Mexico, Ky.
Property in Crittenden county.
King, J., (61).
93. Koon, C. B. Office: Dycusburg, Ky.
Property in Crittenden county.
Koon, C. B., (64).
94. LaRue, Charles. Office: Levias, Ky.
Property in Crittenden county.
LaRue, C., (66).
La Rue Heirs, (67): Agent for.

95. Leander Mining Co., Inc. Kentucky charter, October, 1906. Capital \$10,000. Shares 100. Shareholders 9. Officers: Pres. R. L. Moore; V. Pres. J. G. Rochester; Sec. Treas. C. E. Welson; Gen. Mgr., J. M. Persons, of Marion, Ky. Annual election third Tuesday in October. Directors: G. C. Gray, W. H. Copher, H. B. Morris. Thos. Clifton, of Marion, Ky.
Property in Crittenden county.
White, Leander, (70).
96. Liberty Lead & Zinc Co., Inc. Kentucky charter, Nov., 1902. Capital \$1,500. Office Louisville, Ky.
Officers, Directors: C. & A. T. Pope, Robert Montanus, J. M. Hunter, of Louisville, Ky.
Property in Crittenden county.
Richardson, L.
97. Likens & Others. 1904. Partners: Albert Likens, O. S. Denny and others. Office care of O. S. Denny, Carrsville, Ky.
Properties in Crittenden county.
Bradshaw, W. H., 34½ A., (134).
Burns Reserve, 3 A., (135).
98. Little & Macer. 1904. Partners: S. W. Little and Dr. D. T. Macer, of Evansville, Ind. Office: Care of S. W. Little, Pres., Evansville, Ind.
Property in Crittenden county.
Donakey, C., (56).
99. *Louisville Spar, Lead & Zinc Co., Inc. Kentucky charter, January, 1904. Capital \$25,000. Shares 500.
Office: Louisville, Ky.
Organizers: L. M. Rice, Rush C. Watkins, Ira F. Brainard, J. T. Rice, of Louisville, Ky.
Property in Crittenden county.
Eaton, G. W., (40).
100. Lowery, Tom. Office: Salem, Ky.
Property in Livingston county.
Lowery, T., (155).
101. Lucile Mining Co., Inc., Kentucky charter, Aug. 18, 1902. Capital, \$100,000. Shares, 1,000. Office: Marion, Ky.

Officers, Directors: Pres., John F Harth, Paducah, Ky.;
V. Pres., Jos. Harth, Caseyville, Ky.; Sec.-Treas.-Gen-
Mgr., J. R Finley, Marion, Ky.; L. Harth.

Property in Crittenden county.

Bigham, Robert, (76).

102. Manley Brothers. Office: Levias, Ky.

Property in Crittenden county.

Manley, (78).

103. Marble, Wm. Office: Paducah, Ky.

Property in Caldwell county.

Marble, (185).

104. Marion Lead & Zinc Co., Inc. Office: Care of Wm. H.
Clark, Agt. and Atty., Marion, Ky. Holds property
but gives no list.

105. Marion Mineral Co., Inc. Kentucky charter, April 15,
1902. Capital, \$100,000. Shares, 1,000. Office: Mar-
ion, Ky.

Directors: Pres., R. Emmett Cooper, Hopkinsville, Ky.;
V. Pres., O. L. Bass, Pensacola, Fla.; Sec.-Treas., Z.
J. Crider; Q. A. Elliot, Hopkinsville, (?) Ky.; T. H.
H. Cochran, Marion, Ky.

Property in Crittenden county,

Milliken, W. W., (86).

Miller Heirs, (93).

Pogue, M. F., (97).

In Hardin county, Illinois.

Lee mine, F.

106. Marion Zinc Co., Inc. Wyoming charter, March 1902,
Capital, \$600,000. Offices: Cheyenne, Wyo.; Fort
Wayne, Ind. and Marion, Ky.

Officers, Directors: Pres.-Gen. Mgr.-Eng.. C. S. Knight,
Ft. Wayne, Ind.; 1st. V. Pres., Jno. Q. Boss, Ft. Wayne,
Ind.; 2nd V. Pres., W. R. Cheney, Redland, Cal.; Sec.-
Treas., M. L. Polhamus, Ft. Wayne, Ind.; Wm. Fleming,
L. Centlivre, G. P. Evans, of Ft. Wayne, D. C. Griffith
and O. S. Runnels, of Indianapolis, Ind.

Properties in Crittenden county.

Adams, W. H.

Belt, B. W. (12).

- ‡Bennett, G. W., L.
Brown, W. H., L.
‡Champion, Robert, F.
Daniel, H. D., L.
Davenport, A. A., (36).
LaRue, R. A., L.
Riley, J. N., (103).
In Livingston county.
? Adams, David, L.
? Baxter & Riddle, L.
McDowell, M., (157).
In Caldwell county.
Lowery, M. B., (184).
Ray, J. B., (187).
107. Maxwell, Milton. Office: Fredonia, Ky.
Property in Caldwell county.
Maxwell, M., (186).
108. Maxwell, Blue & Nunn. Office: Marion, Ky. Partners:
P. S. Maxwell, J. W. Blue, Jr., C. S. Nunn, of Marion,
Ky.
Property in Crittenden county.
Cark, Eby., 84 A., F
109. McFee Heirs. Office: Marion, Ky.
Property in Crittenden county.
McFee Heirs, F.
Barnes, J., M. R.
110. McReynolds, — Office: ? Pod, Ky.
Property in Christian county.
McReynolds, (201).
111. Moore Estate. Office: Care of Executor J. Handy Moore
Estate, Charleston, Mo.
Property in Crittenden county.
Belt, T. D., F.
Bracy, Newt., F.
Heath, S. M., (55).
Pickens, A., F.
112. Montanus, Robt., and Other. Office: 118 W. Market St.,
Louisville, Ky.
Property in Livingston county.
Lowery, J. S., (154).

113. Moreland, J. R. Office: Salem, Ky.
Property in Livingston county.
Moreland, J. R., (158).
114. Morganfield Mining Co. 1904. Office: Morganfield, Ky.
Officers: Pres., ——— Higgensderfer; Sec.-Treas., J. L. Harris; Gen. Mgr.-Supt., A. D. Noe, of Morganfield, Ky.
Properties in Crittenden county.
LaRue Shaft, L., (69).
Love, Mrs. E. M., F. (69).
115. Mountain Lead, Zinc & Fluorspar Co., Inc. Kentucky charter, October 20, 1903. Capital, \$150,000, of which \$50,000 is treasury stock. Office: Paducah, Ky.
Officers, Directors: Pres., W. D. Greer; V. Pres., J. A. Rudy; Sec.-Treas., Wm. Marble; J. L. Friedman, E. P. Gilson, G. C. Hughes, of Paducah, Ky.
Property in Crittenden county.
Part of Crittenden Springs Tract, 18A., M. R., and 5A., timber, (109) .
116. Newkirk, A. Office: Cleveland, O.
Property in Crittenden county.
Tabor, J. I., (91).
117. Nine Acres Mining Co, Inc. 1907. Capital, \$100,000.
Officers: Shares, 1,000. Office: Marion, Ky.
Property in Crittenden county.
Nine Acre Mine, (92).
Nine Acre Mill.
118. Ohio Mining Co. 1906. Office: Columbus, O.
Officers: Sec.-Treas., E. G. Orebaugh; Gen. Mgr., W. J. Phillips, of Columbus, O.; Supt., T. Grant Davidson, Marion, Ky.
Property in Crittenden county.
Lynn, W. C., MR. A shaft is being sunk and is about 70 feet deep.
119. Paducah Lead, Zinc & Fluorspar Co., Inc. Kentucky charter, August, 1902. Capital, \$20,000. Office: Paducah, Ky.
Organizers: Geo. C. Hughes, Geo. C. Wallace, Ed P. Noble, Geo. O. Hart, Ed P. Gilson, Sol. Dreyfus, J. L. Friedman, of Paducah, Ky.
Properties in Crittenden county. (232 A).

- Kirk, Jake, F.
Kirk, Linford, F.
Walker, Chas., F.
120. Pickens, Albert, and Others. 1906. Office: Marion, Ky.
Properties in Crittenden county.
Glendale, (49).
Terry, Blake, (71).
121. Pierce, J. A. Office: Salem, Ky.
Property in Livingston county.
Pierce, J. A., (163).
122. Pierce, J. C. Office: Marion, Ky.
Property in Crittenden county.
Stephenson, Rush, (107).
123. Pogue, M. F. Office: Francis, Ky.
Property in Crittenden county.
Crane Bros., F.
124. Pogue & Matthews. Office: Francis, Ky. Partners: M.
F. Pogue & John Matthews, of Francis, Ky.
Property in Crittenden county.
Matthews, John, F.
125. Pogue and Others. Office: Francis, Ky. Partners: M.
F. Pogue, John Matthews, F. M. Matthews and S. H.
Mathews, of Francis, Ky.
Property in Crittenden county.
Matthews, John, F.
126. Pogue, Asbridge & Oliver. 1903. Office: Francis, Ky.
Partners: M. F. Pogue, W. E. Asbridge, W. F. Oliver,
of Francis, Ky.
Property in Crittenden county.
Simpkins, J. J., L.
127. Polk, John. Office: Dycusburg, Ky.
Property in Crittenden county.
Polk, J., (98).
128. Polk, Wm. Office: Mexico, Ky.
Property in Crittenden county.
Polk, Wm., (99).
129. Pope, C. & A. T. 1902. Partners: Dr. Curran Pope &
A. Thruston Pope. Office: 111-113 W. Chestnut St.,
Louisville, Ky.
Properties in Crittenden county.

- Babb, T. J., (5).
Barnes, J. H., MR.
Conyers, John, MR.
Grimes, S. R., (145).
LaRue, R. A., (66).
Lowery, W. S., MR.
Pace, Jos., MR.
Sisco, Press, L.
Tynor, W. C.
Utley, J. A. & Michel, S. L., (116).
Watson, A. H., (120).
Properties in Livingston county.
Foreman, L.
Martin, Thos., (156).
130. Princeton Lead & Zinc Co., Inc., 1902. Office: Care of J. W. Hollowell, Princeton, Ky.
Property in Caldwell county.
Dunning, (180).
131. Pue, James. Office: Golden Pond, Ky.
Property in Trigg county.
Pue, (218).
132. Ramage Brothers. H. C. & C. N Ramage. Office: Salem, Ky.
Property in Livingston county.
Ramage, (164).
133. Redd, Jesse (col.) Office: Dulaney, Ky.
Property in Lyon county.
Redd, J., (206).
134. Red Hill Mining Co., Inc. Kentucky charter, 1906. Capital, \$30,000. Shares, 300. Offices: LaGrange and Marion, Ky.
Officers, Directors: Pres.-Gen. Mgr., Walter Bennett; V. Pres., C. M. Oglesby; Sec.-Supt., W. Horace Oglesby; Treas., R. T. Adams, of LaGrange, Ky.; Consult. Eng. John L. Harpending, Marion, Ky. Annual election, second Tuesday in January.
Property in Crittenden county.
Vaughn, D., (101).

135. Reed, Mrs. John. Office: Kuttawa, Ky.
Property in Crittenden county.
Hardin, Mrs., (54).
136. Reed Mining Co., Inc. South Dakota charter, October, 1902. Capital, \$500,000. Offices: Pierre, S. D., and Marion, Ky.
Officers: Pres., L. W. Cruce, Ardmore, Ind. Ter.; Sec.-Treas., D. C. Roberts, Carthage, Tenn.; Supt., Geo. P. Roberts, Marion, Ky.
Property in Crittenden county.
Reed land, 23 A.—F. and 100 A.—MR. Some prospects show pyrite and clay. Last prospected about 1904.
137. Reiter, Mrs. Carrie. Office: Fredonia, Ky.
Property in Crittenden county.
Reiter, (102).
138. Roberts & Co., Geo. P. 1903. Office: Marion, Ky. Gen. Mgr., Geo. P. Roberts. Buy fluorspar and sell to consumer.
139. Rochester and Others. 1903. Office: Care of J. G. Rochester, Marion, Ky.
Properties in Crittenden county.
Akers, Flem, (3).
Milliken, W. W., 5 A.,—F.
140. Rovianck and Others. Office: Pittsburg, Pa. P. V. Rovianck and Others.
Property in Crittenden county.
Hodge, Ebbie, (41). ? In litigation.
141. Royal Lead & Spar Co., Inc. Kentucky charter, July 17, 1902. Capital, \$10,000. Office: Paducah, Ky.
Officers, Directors: Pres., Ed Wolfhawk; V. Pres., Stanley Dubois; Sec., W. F. Paxton; Treas., S. B. Hughes; Jos. L. Friedman, Wm. Wades, Geo. Rock, Geo. C. Wallace, of Paducah, Ky.
Property in Livingston county.
Royal Mines, (165). MR in litigation.
142. Sanders Ore Separating Co., Inc. Kentucky charter,

- December 6, 1905. Capital, \$20,000. Shares, 200
Office: Marion, Ky.
Officers, Directors: Pres., Walter Sanders, New York, N. Y.; V. P., Gen. Mgr., W. Murray Sanders; Sec.-Treas., Cyril C. Sanders, of Marion, Ky. Annual election October.
- Property in Crittenden county.
Sanders Mill.
143. Satterfield, ———. Office: Princeton, Ky.
Property in Caldwell county.
Satterfield, (188).
144. Schoolfield-Spees Mining & Milling Co., Inc. West Virginia charter, April, 1906. Capital, \$100,000. Shares, 100,000. Officers: Main, Newport, Ky.: branch, 609 Crescent Ave., Covington, Ky.
Officers, Directors: Pres., Wm. A. Young, Dayton, Ky.; V. Pres., W. R. Bollman, Cincinnati, O.; Sec.-Treas., John Percival, W. Covington, Ky.; Gen. Mgr., F. E. Schoolfield, Covington, Ky., and Thos. B. Lantry; Supt., A. M. Abbott, Covington, Ky. Annual election, April 1.
Property in Livingston county.
Spees, Tom, (165).
145. Senator Mining Co., Inc., Kentucky charter, September 15, 1902. Capital, \$100,000. Shares, 1,000. Office: 413 Columbia Bldg., Louisville, Ky.
Officers: Pres., Basil Doerhoefer; V. Pres., B. F. Weitzel, of Louisville, Ky.; Sec.-Treas., Thos. P. Waddell. Millersburg, Ky.
Property in Caldwell county.
Senator Mines, (189).
146. Sisco, Press. Office: View, Ky.
Property in Crittenden county.
Lewis Bros., (72).
147. Smith, Chas., (col.) Office: Grand Rivers, Ky.
Property in Lyon county.
Smith, C., (207).
148. Spencer, Wm. Office: Fordsferry, Ky.
Property in Crittenden county.
Barger, T. J., (7).

149. Sullenger, S. S. Office: Irma, Ky.
Properties in Crittenden county.
Sullenger, (110).
Swansey, F.
Wolsey, Jos., (123).
Property in Livingston county.
Watson, Dallas,—F.
150. Sullenger, Lee. Office: Sheridan, Ky.
Property in Crittenden county.
Madrid, Widow. This was prospected in 1900 by the Buckeye Mining Co., who opened a narrow vein of calcspar with traces of fluorspar, lead and zinc. Later gravel fluorspar was found 20 feet N. W. of the master fault of the Corn fault zone, which passes through this property.
151. Sutts, ———. Office: Hardesty, Ky.
Property in Livingston county.
Sutts, (167).
152. Temme and Others. 1904. Partners: A. F. Karges, J. C. Zutt, Wm. H. Temme, Jno. Weber, Jno. Jordan, of Evansville, Ind. Office: Care of W. H. Temme, Evansville, Ind.
Properties in Crittenden county.
Clark, J. A.—F.
Clement, I. H.—F.
Dalton, W. L., (32).
French, Alex.,—F.
Jones, David,—F.
Sullenger, Jas. E.,—F.
Weldon, C. E.,—F.
153. Terry, W. P. Office: Marion, Ky.
Property in Crittenden county.
Terry, W. P., (113).
154. Terry Heirs, Gus. Office: Markam Terry, Agent, Sheridan, Ky.
Properties in Crittenden county.
Terry, G.,—160A., (114).
Terry, G., 300 A.,—F.
155. The Albany Lead, Zinc & Fluorspar Co., Inc. Arizona charter, 1906. Capital, \$200,000. Shares, 200,000. Offices: Phoenix, Ariz., and Albany, Ind.

Officers, Directors: Pres., Norman Russell; V. Pres., Robert Braunner; Sec., W. E. Hodson; Treas., Arch McCormick; M. B. Baird, Oliver Dick, Jos. Zehner, Walter McCormick, of Albany, Ind.; Supt., C. E. Radcliffe.

Property in Crittenden county.

Perkins, Sam. L.

156. *The Crittenden Mining Co., Inc. Kentucky charter, October 17, 1903. Capital, \$100,000. Offices: Henderson and Marion, Ky.

Officer: Pres., F. Haag, Henderson, Ky. Directors: F. Haag, J. O. Clore, Mrs. Ida Pearsons, Col. Starling.

Property in Crittenden county.

Flanary, R. E., (45).

157. *The Farmland Mining Co., Inc. June 1903. Office: Pres. C. E. Foster, Farmland, Ind.

Property in Livingston county.

Lindley, I., (152).

Property in Crittenden county.

Bennett land,—L.

158. The Great Northern Mining & Milling Co., Inc. Arizona charter, April 14, 1903. Capital, \$200,000. Shares, 200,000. Offices: Main, Pheonix, Ariz.; branch, Muncie, Ind.

Officers, Directors: Pres., Thos. H. Kirby; V. Pres., Wm. Campbell; Sec., J. Walter Baird; Treas., Chas. M. Staijers, James M. Motsenboche, M. A. Cunningham, Clyde Emdee, W. L. Curtis, Thos. H. Kirby, R. M. Carter, Chas. P. Smith. Supt.-Gen.-Mgr., John R. Steinman, Crittenden Springs, care Marion, Ky.

Properties in Crittenden county.

Franks, Mrs. Martha 50 A., (1).

Guill, A. A. 91A (52).

159. The Henderson Co., Inc. Kentucky charter, September 28, 1903. Capital, \$70,000. Office: Henderson, Ky.

Officers, Directors: Pres., David Clark; V. Pres., John Reichart; Sec.-Gen.-Mgr., Julius Baldaup; Treas., Charles E. Dallam, Morris Baldaup, Edward A. Jonas, Henry Kleymeyer, of Henderson, Ky.

Properties in Crittenden county.

Farmer, Widow, (65).

Deboe, (65).

Thomas, J. E.,—F.

160. The Hopkinsville Co., Inc. Arizona charter, 1903. Capital, \$1,000,000. Shares, 1,000,000. Office: Hopkinsville, Ky.

Officers, Directors: Pres., Lee Ellis; V. Pres., Frank Rives; Sec., L. L. Elgin; Treas., Jas. West, B. B. Rice, W. M. Shaw, P. E. West. Annual election, January.

Property in Crittenden county.

Meyers, W. H., (85).

161. The Shady Grove Mining Co. 1903. Office: Salem, Ky.

Officers, Directors: Pres.-Supt., J. S. Waggoner; Sec., J. B. Simpson, of Salem, Ky.; Fred Casner, J. B. Elder, Jas. McConnell, Jeff McConnell, M. D., T. E. Utley, Thos. Cannon.

Properties in Crittenden county.

Croft, J., (83).

Damron. J. W. S., (34).

Property in Livingston county.

Linley, I., (132).

162. The Union Central Mining Co., Inc. South Dakota charter, May 27, 1901. Capital, \$500,000. Office: 29 Euclid Ave., Room 8, Cleveland, O.

Officers: Pres., W. D. Hills; V. Pres., A. E. Fowler; Sec.-Treas., H. M. Fiske, of Cleveland, O.; Gen. Mgr., Cornelius Newkirk, 139 Beach St., Cleveland, O.

Properties in Caldwell county.

Dodds, (179).

Stone, Joe, (190).

Tabor,—L.

163. Trabue, I. H. Office: Punta Gorda, Fla. Holds numerous mining rights in Livingston county.

164. Underdown, R. P. Office: Marion, Ky.

Property in Crittenden county.

Underdown, R. P.—F.

165. Waddell, T. L. Office: Salem, Ky.

Property in Crittenden county.

Waddell, T. L., (117).

166. Waddlington, Lloyd. Office: Kuttawa, Ky.
Property in Lyon county.
Waddlington, L., (208).
167. Wallingford, W. D. Office: Marion, Ky.
Property in Crittenden county.
Wallingford, (119).
168. *Western Clay & Mining Co., Inc. 1904. Office: Kewanee, Ill.
Pres., A. M. Hewlett, Kewanee, Ill.; Sec., C. I. Pierce, St. David, Ill.
Properties in Crittenden county.
Babb, T. L. Option.
Foley, J. D.—F.
Franklin, J. L., F. (20).
Stevens, C. R., (108).
Properties in Livingston county.
Bramfield, M.—M. R.
Cooper, Geo. W.—M. R.
Davis, C. B. & Dunn, D. A.—F.
Deboe, Mrs. D. A.—F.
Heyward, Mrs. M. C.—M. R. (2 tracts).
McGuire, R. H.—M. R.
Norton, W. F., (162).
Smith, Chas.—M. R.
Tisdale, (171).
Threlkeld, W. T.—M. R.
Ward, T. J.—M. R.
Wayrick, J. F.—M. R.
Woods, H. W., (173).
Woods, R. II., (174).
169. Wheatcroft Mineral Co., Inc. South Dakota charter,
? December, 1903. Capital \$100,000. Shares, 100,000
Office: Wheatcroft, Ky.
Officers, Directors: Pres., Irving H. Wheatcroft; Sec.,
Edwin C. Ruff; Treas., A. E. Cullen, E. Curry, B. H.
Curry, of Wheatcroft, Ky.; V. Pres., T. A. Conway,
Marion, Ky.
Property in Crittenden county.
Wheatcroft Mine, (121).

170. White, Mrs. Leander. Office: View, Ky.
Property in Crittenden county.
? Crosson, (31).
171. Wigginton, Dick. Office: Fredonia, Ky.
Property in Caldwell county.
Wigginton, (192).
172. Williams, L. G. Office: Hopkinsville, Ky.
Property in Christian county.
Williams, L. G., (202).
173. Wilson, R. W. Office: Marion, Ky.
Property in Crittenden county.
Crittenden Springs tract, 600 A., (122).
174. Wright, Prof. Office: Carrsville, Ky.
Property in Livingston county.
Wright, Prof., (175).
175. York, Heyward. Office: View, Ky.
Property in Crittenden county.
York, (125).
176. Young, Thomas. Office: Henshaw, Ky.
Property in Webster county.
Young, T., (220).
177. Unknown.
Property in Trigg county.
Ohara shaft (214).
178. Southern Lead & Zinc Co., Inc.
Kentucky charter, Jan. 1907.
Capital \$50,000. 100 shares preferred; 400 shares common stock; \$100.00 per share.
Offices: Main, 88 Kenyon Bldg., Louisville, Ky. Branch: Marion, Ky.
Officers, Director: Pres. E. F. W. Kaiser; V.-Pres. and Gen. Mgr., Jno. Drescher; Sec.-Treas., Peter Knopp, Jr.; Wm. Bohon; R. W. Bingham; Supt., R. D. Drescher.
Property in Crittenden county.
Columbia Mines, S. L. (28).

LIST OF FORMER OPERATORS.

The following is a list of the names of those previously operating or holding mining property in the District but who have either been absorbed by new ones, reorganized, or ceased to exist. The numbers following the names refer to the number given the operator in the foregoing table that now holds the property or properties formerly held by those whose names are here given. The date given is approximately the date operations were begun by previous operators; a * before a date indicates previous to date given.

- Archer, W. G., & Delker, J. G., 1904. 10.
Beck & Davis; David Beck and Walter Davis, 1875. 87,
168.
Belt, B. W., & Sullenger, 1880. 106.
Bement, G., Wm., Jr., & Schwab, M., 1902. 134.
Big Five Mining Co., 1904. 120.
Bigham, R. B., 1899. 101.
Bozeman & Co., 1902. 42.
Brown, S. S., & Ward, James, 1890. 87.
Burns, Pinkney, *1874. 97.
Bush, W. P. D., & Co., 1865-6.
Casey, N. W. & Co., 1865-6.
Chicago Mining Co., Inc., 1901. 101.
Chittenden, J. E. & others, 1904. 5.
Cincinnati Lead & Spar Mining Co., 1882. 31, 87.
Clark, J. A., & Others, 1902. 106.
Clement, Dr. I. H., 1904. 152.
Clement, R. B., 1899. 77.
Cleveland Mining & Reduction Co., Inc., 1901. 59.
Columbia Silver Mining Co., 1866. 31.
Conway, T. A., & Others, 1903. 153.
Cook, Capt., 1903.
Cook, Judge J. T., 1903. 55.
Cooley, S. W., 1895. 87.

- Corn Brothers, 1900. 13, 61.
Cox, James, 1898. 1, 4.
Delaware Mining Co., 1904. 113.
Drake, Barnes & Co., 1899. 1, 4, 103.
Drescher & Co., 1905. 31.
Eaton, G. Wesley, 1901. 99.
Flanary, R. E., 1901. 71, 73, 156.
Fredonia Mining & Smelting Co., 1902. 87.
Garnett Brothers, 1902. 26.
Givens, Ross, and others, 1904. 82.
Givens, J. W., Drygoods Co., 1902. 61.
Glass, Henry, 1866. 31, 87.
Golconda Milling & Mining Co., 1904. 148.
Halliday & Green, about 1870. 31.
Harris, J. L., 1902. 21.
Harris, W. G., 1903. 68.
Harth Brothers & Finley, 1902. 101.
Hewlett, A. M. & M. L., Dr. Callahan and ——Waller,
*1870. 168.
Heyward, E. J., & Morse, J. H., 1902. 1.
Jackson, Andrew, 1835. 31.
Kennedy & Co., W. L., 1904. 54.
Kentucky Fluorspar Mining & Manufacturing Co., Inc.,
1902.
Kentucky Lead & Fluorspar Co., Inc., of Tenn., 1897. 31.
Kevil, D. B. and others, 1901. 160.
Keystone Lead & Zinc Co., 1904. 38.
Langenbach & Morton, 1900. 1, 4.
LaRue, Wm., 130.
Louisville-Marion Mining Co., 1904. 95, 158.
Marble, S., & Son, 1875. 103.
Marion Fluorspar Co., 1899. 160.
Marion Zinc Co., of Ky., 1902. 106.
Maxwell, P. S., and others, 1892. 32.
Mayes & Wilson, 1901. 173.
McChord, H. C., 1904.
McGraw, J., 1903. 20.
Memphis Lead Mining Co., 1872. 87.
Miller, C. M., 1900, 1, etc.
Miller, J. C., 1898. 12.

- Moody, F. B., about 1870. 38.
Morris, —, 1880. 8.
Ogden & Curry (The Westside Mining Co.) 1904. 86.
Ohara, M. C., 1900. 95.
Ohio Valley Mining Co., 1902. 5, 33, 174.
Pittsburg Fluorspar Mining & Manufacturing Co., 1903.
38.
Pittsburg Mining & Reduction Co., Inc., 1900. 38.
Porter, D. C., 1904. 160.
Porter & Hudson, 1896. 31.
Postelwaite & Watkins, 1897. 59.
Ratliffe & Williams, 1902. 97.
Reed, R. M., and others, 1903. 159.
Republic Mining Co., Inc., 1900. 56, 94, 99, 129.
Riley, J. N., 1901. 106.
River Valley Mining Co., *1870. 140.
Roberts, D. C., 1903. 99, 129.
Safford, A. B., & Co., 1865-66.
Samples, and others, 1903. 140.
St. Louis Mining Co., prospected Eberly land, 1900.
Southern Mining & Promotion Co., 1902. 54.
Sullenger, James, 120.
The Buckeye Mining Co., Inc., 1901. 150.
The Buffalo Mining Co., 1903. 74.
The Carrsville Mining & Milling Co., Inc., 1902. 97.
The Commercial Mining & Smelting Co., Inc., 1902. 87.
The Dycusburg Lead Mining Co., 1880. 87.
The Fluorspar Co., Inc., 1898. 87, 140.
The Globe Spar Co.
The Livingston County Land & Mining Co., *1902. 168.
The Mineral Point Zinc Co., Inc., 1903. 87.
The National Lead, Zinc & Fluorspar Co., Inc., 1900. 103.
The Ohio Zinc Co., Inc., 1902. Prospected Kam Hardin
land.
The Sea Coast Mineral Co., Inc., operated dry mill at
Paducah for ore separation, 1902-4.
The Sumner Marble Co., 1903. 103.
The Winifred Mining Co., Inc., 1903. 23.
Tolu Mining Co., 1901.
Tyrie, —, 87.

- Waggoner, J. W., 1893. 38, 87, 106.
Waggoner, J. S., and others, 1901. 132, 161.
Wallace, Wm., and others, 1902. 54.
Walker, R. C. and others, 1902. 52.
Walton Spar Mining Co., Jos. Walton, 1883. 87.
Watkins, Harry, 1898. 12, 22, 62, etc.
Western Kentucky Mining Co., Inc., 1899. 31, 36, 45, 87,
106, 117, 158.
Williams, L. G. and others. 57.
Wilson Mining Co., 1903. 173.

APPENDIX I.

OCCURRENCE OF COBALT AND NICKEL IN WESTERN KENTUCKY.

The presence of cobalt-nickel-bearing wad in the Western Kentucky Lead, Zinc and Spar District was first discovered at the main shaft of the Givens mines about 1904. As the discovery caused considerable excitement it led to a thorough search for the mineral, resulting in its being found at a number of localities. The demand for cobalt was much stimulated by Edison's discovery of its value for use in storage batteries, and this encouraged further investigation of its occurrence here.

The occurrences investigated are of four types: (1) In narrow veins or small pockets in residual clay, or coating chert in such clay from the St. Louis limestone; (2) In small seams in Birdville quartzite associated with sand and indianayite; (3) In the magniferous iron ore of the St. Louis residuals; and (4) In small seams, pockets and flats in a limonitic clay bed in Birdsville rocks. Of these, the two former types are associated with the veins, faults and dikes, while the last two are not.

The mineral is brown to black in color, sometimes with a reddish-purplish tinge. The analyses show good percentages of manganese and iron. In some of the specimens in which no quantitative determination of these elements were made, they are present in even greater quantity than in some of those in which the percentages were determined. As will be seen by inspection of the analyses, the percentages of cobalt, nickel, zinc and lead are very minute, in the best selected material the cobalt content being only 2 per cent. and the highest percentage of nickel 0.33 per cent; this in the same specimen. The analyses made by Dr. A. M. Peter, Chemist of the Survey, show generally a lower percentage of these metals than those reported by private chemists who analyzed the material for the companies; analyses of which I have learnt from private sources reporting as high as 3 per cent. cobalt and 1.76 per cent. nickel. The methods employed by Dr. Peter were as refined as possible, so we may accept them as conservative and

probably the nearest correct. The lead which occurs in minute quantities is in a curious mixture, which Dr. Peter thinks contains rare earths such as gallium, etc.; this partly in association with the small zinc content. The best results in cobalt-nickel content were found in that part of the black material which was a rather compact, smooth mineral, soapy to the touch and soiling the fingers like graphite. That selected from the green shale gave the best results, the shale itself showing, however, no cobalt or nickel upon qualitative test.

The wad occurs only in seams less than four inches wide, except at the main Givens mine, or otherwise only in small quantity through the clay or shale, and as the samples do not represent in any case averages of the material as mined but, instead, either select material associated with some clay or shale, or else very select material picked from this, it is apparent that the quantity of wad obtainable must needs be very small. This, when considered together with the small quantity of the metals in the select wad, makes the occurrences insignificant from a commercial standpoint and only of interest scientifically. The deposits, except, perhaps, that at the Givens shaft, concerning which the writer has not sufficient information to justify a definite statement, are unworthy of further consideration as cobalt-nickel ores. The deposit of ferromanganese ore at the Jesse Redd place, if in quantity, should be valuable in the manufacture of spiegeleisen, an iron in which 20 per cent. of manganese is desirable.

DETAILS OF PRINCIPAL OCCURRENCES.

THE BRYANT ADIT.

The Bryant adit was driven to prospect the ground in the vicinity of the mica-peridotite dikes which traverses the Bryant land. It is 3 miles west of Marion. Though somewhat irregular in shape, it bends from northwest to northeast, forming the segment of a circle, the chord of which strikes about N. 20° E. For the first 75 feet, a stratified clay, brown and white color, plastic, and resulting from the decomposition of shaly sandstone, was passed through. This clay grades irregularly into quartzite. At 105 feet from the entrance, a dike was encountered. The dike strikes northwest probably not less than

30 degrees. A branch drift was started immediately east of where the dike was encountered and was driven N. 20° W. for 45 feet. The first section of this drift had yellow decomposed mica-peridotite on the west. Clay with irregularly shaped limonite masses and veins occur on the east, and beyond the peridotite, on the west, where some sandstone also is intermixed. At 14 feet from the end, a sheet of quartzite was found, persisting to the end at 2 feet above the bottom of the drift and into the roof. Below and on either side is shale. This block, from 14 to 24 inches in thickness, was apparently faulted into the shales striking N. 17° W., the faulting not following into the shale below.

Taking out the east or main limb of the adit, we find quartzite extending for 15 feet, when a fault N. 24° E., and dipping 44° to 54° southwest, is to be seen. For 2 feet from the bottom of the dike gray shales underlie the quartzite, the strata dipping 17 feet southwest. Quartzite forms the east wall. For the first few feet this quartzite is much brecciated, but shortly beyond the quartzite dips west and the quartzite is faulted with faults of $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch displacement. Typical wedge faulting, with parallel faults paralleling the dip of one of the major border faults and setting up a repetition of wedge faulting, has taken place. The faults on either side of the main block are compensating. A bed of shale dips under the quartzite and evidently this shale fills the entire drift. The quartzite and shale dip irregularly 28° to 40° northwest, with strikes ranging from N. 47° to 57° E. In the quartzite, a vein of black earthy wad, from $\frac{1}{2}$ to 2 inches wide, separated into two bands by a seam of nearly white or pinkish clay containing 23.9 per cent. water and hence similar in composition to indianait, somewhat sandy, fills the space between them and makes up the bulk of the vein. This vein does not persist downward from the quartzite into the shale, but ends abruptly upon reaching the shale. It strikes N. 80° E. A second vein of like character was also noted. Analyses Nos. 2693, 2708, and 2709 are of samples from these veins.

CAMPBELL PROSPECT.

This is located 5½ miles southwest of Mexico, on the land of Mr. T. C. Campbell. A short distance southwest of the fault which crosses the Campbell land and has Birdsville

rocks and St. Louis limestone for walls in a drain-like depression in St. Louis residuals, a small hole dug by the writer yielded about a bushel of wad in about a half hour, at but a few inches below the surface. It could not be determined whether it former part of simply a local pocket or of a vein. No analyses were made of this product, but it must contain a goodly percentage of manganese and likely, also, small percentages of the other metals.

GIVENS COBALT PROSPECTS.

The Givens cobalt prospects are situated 9 miles west of Marion, and are on the property of the Givens Mining Co. The main shaft, sunk upon Dr. Smith's suggestion, was put down to a depth of 105 feet. A cross-cut level was run at 70 feet, which the writer examined. In the south cross-cut, the features of most interest are 2 feet of purplefluorspar with little quartzite, and 13 feet of quartzite, fluorspar (both lump and gravel) and kaolin, the last two in seams and pockets through the former. These all dip at a high angle south. There is every reason to believe that this kaolin is a decomposition product of ingredients of the quartzite (possibly feldspathic ingredients). In the north cross-cut the notable features are a block of dropped-in shale, a vein of 2 to 4 inches of cobalt-manganese ore, and alternate bands of clay and cherts and limestone. The main fault plane lies at the north end of the fluorspar-kaolin-quartzite band and strikes about N. 60° E. The water level is at a depth of 70 feet. The cobalt-manganese vein which changes from soft to hard ore some distance below water level is said to be 14 inches in width at the bottom of the shaft.

The fault is a master fault between Birdsville and St. Louis rocks and belongs to what has been termed the Corn fault zone.

On the north of the fault zone, bearing practically the same relations as those above described, are two prospects each 20 feet in depth, about one-half mile northeast. Here the product occurs through red-brown clay, in cavities one to three inches in diameter, which it incrusts and partly fills, and in veins

under two inches thick; also as a thin coating on flints. The samples analyzed, Nos. 2705, 2706, 2706a and 2707 were all collected at the last two prospects.*

MILLIKEN SHAFT, YANDELL MINES.

The Kentucky Fluorspar Co. in sinking the Milliken shaft encountered wad in the partly altered Ohara shale, within 20 feet of the surface and mixed with red clay of the St. Louis foot-wall in the lower part of the shaft, which is 100 feet deep. The red clay also has red clay and gravel fluorspar associated. The wad of the green shale shows heavier percentages of both cobalt and nickel than that of the red clay, and in fact than in that of any of the other products analyzed. Analyses Nos. 2772, 2773, and 2773a give the character of the Milliken product.

The shaft is located on the Kentucky vein, striking N. 65° E., which belongs to the Tabb fault zone and is about three miles southwest of Mexico. A heavy body of gravel fluorspar, also some white lump, was found in this shaft.

PARISH SHAFT.

The Parish shaft, operated by the Kentucky and Indiana Mining Co., is about a quarter mile northeast of the above, on the same fault zone. A bed of fluorspar of considerable thickness replaces the St. Louis limestone wall for some distance out, horizontally, from the fault. Cavities in this fluorspar are found encrusted with a thin coating of wad, of which the quantity capable of separation was so small that while manganese was detected, cobalt and nickel, if present, could not be determined, (See Analysis 2774.) A sample of the clear purple fluorspar, as shown by the analysis No. 2770, contained none of the metals, hence the purple coloring is not dependent on the presence of any of these metals, and their association as a coating in the cavities is only incidental.

RILEY MINE.

The Riley Mine is about 7 miles southwest of Mexico, on the property of the Marion Zinc Co. It is on the Riley fault of the Excelsior (Marion) fault zone and has Birdsville and St.

Louis walls. In a stope above the drift, at the 35 foot level northeast from the main shaft, in the red clay, the galena-fluorspar vein and the St. Louis limestone wall on the southeast of the fault, a 2-inch vein of wad was noted. No analyses of this material were made, but it appears very similar to the Givens.

WALLINGFORD PROSPECT.

This is $1\frac{1}{2}$ miles east-northeast of Marion, on the W. D. Wallingford land. It is a shallow pit, sunk in Birdsville shales about 6 feet. At 3 feet from the surface, a 3-foot bed of yellowish limonitic clay was found, underlying shale. In this clay brown wad occurs in small seams, pockets and flats. Analysis No. 2771 of a sample from this prospect shows a small content of cobalt, nickel, etc. It is apparently not connected in any way with a vein, although a fault crosses the same land within about a quarter mile of it.

JESSE REDD PROSPECT.

On the land of Jesse Redd (colored), 3 miles southwest of the Illinois Central Railroad at Dulaney, in a prospect in the red clay of the St. Louis limestone, a deposit of manganese-bearing iron ore was found. The ore occurs in lumps scattered through the clay and chert. The analysis shows, beside minute percentages of cobalt and nickel, 21 per cent. of manganese and 30 per cent. of iron, making an ore having a composition similar to spiegeleisen, for the manufacture of which, should the ore be found in quantity, it would be adaptable.

Following are analysis of samples, made in the laboratory of the Survey:

ANALYSIS OF WESTERN KENTUCKY WAD, ETC., SHOWING COBALT-NICKEL CONTENT.

A. M. Peter, Chemist for the Survey Analyst.

Locality.	Man-ganese.	Iron.	Cobalt.	Nickel.	Zinc.	Lead.
Bryant Adit: Black Wad through Indianaite. (2693)	present	present	0.139	0.072	a little	trace.
Bryant Adit: Wad. (2708)	present	present	0.011	0.011	a little	trace.
Bryant Adit: Wad coating on quartzite. (2709)....	present	present	0.041	.051	0.085	trace.
Givens Cobalt Prospect: Wad in red clay. (2706)	present	present	0.050	0.004	0.296	trace.
Givens Cobalt Prospect: Selected wad of 2706. (2706a).....	2.100	6.800	0.140	0.020	n. e.	trace.
Givens Cobalt Prospect: Selected wad. (2705)...	6.000	present	0.084 0.108	n. e.	n. e.	trace.
Givens Cobalt Prospect: Wad coating on flint. (2707).....	present	present	0.006	0.098	n. e.	trace.
Milliken Shaft: Wad in red clay. (2772).....	0.910	present	0.010		0.490	trace.
Milliken Shaft: Wad in green shale. (2773)....	2.450	present	0.400	0.040	0.190	trace.
Milliken Shaft: Wad selected from green shale. (2773a).....	present	2.900	2.000	0.330	n. e.	trace.
Parish Shaft: Coating on fluorite. (2774).....	present	present	none?	none?	.....	.....
Parish Shaft: Purple fluorite selected. (2770).....	none	0.027	none	none	none	none
Wallingford Prospect: Wad through limonitic clay. (2771).....	3.110	present	0.170	0.040	0.060	.....
Redd Prospect: Lyon Co., Ferro-manganese ore. (2692).....	21.000	30.000	0.032	0.044	n. e.	.....

The word "present" used in the analysis indicates present in some quantity, but not quantitatively determined.

"n. e." signifies that the amount, if any present, was not determined.

ORIGIN OF THE WAD.

Three different modes of genesis suggest themselves: (1) A concentration by ground waters from the dikes; (2) brought up as fluosilicates with the mineral-bearing waters from which the ores and spars were precipitated; and (3) segregation of small amounts of the metals, originally disseminated in the rocks, upon their weathering and oxidation.

The first may be dismissed when we consider that in only one case where the cobaltiferous-nickeliferous wad has been found, is there a dike nearby, although it is true that an analysis of the mica-peridotite of the Flanary dike shows 0.10 per cent. of nickel oxide, a trace of cobalt, together with a little more manganese than nickel. In relation to the second mode of origin we have negative evidence in the absence of any of the primary cobalt, nickel or manganese minerals in the unaltered fluorspar or ores. Where manganese, nickel and cobalt occur associated with the vein minerals, directly encrusting the mineral as at the Parish, or in the shale, clay or rock nearby, they always occur as oxides and hence suggest secondary origin, which makes the last of the suggested modes the most probable one. Besides, it is the only one which would cover all the occurrences. At the Givens main shaft, where the ore is said to extend to a depth of more than 100 feet, although becoming more compact, it yet remains an oxide in association with residuals of the wall rocks. Wad or bog ore usually originates from concentration or segregation by lateral and descending meteoric waters. Dr. Peter has noted minute quantities of cobalt in other Kentucky wads (in the examination of samples collected by the Survey during the administration of Prof. Shaler), although he has never detected nickel in them before, this leading to the conclusion that the occurrence in the Western Kentucky district is not an unusual one. The presence of nickel and cobalt in the Redd ferro-manganese ore, which, together with other iron ores common in St. Louis residuals, is considered the result of the concentration of minute quantities of the metals from the formerly superposed but now eroded strata, is another point clearly in favor of the hypothesis of the similar origin of the other cobalt-nickel-bearing deposits herein described.

APPENDIX II.

SIMPLE TESTS FOR SOME COMMON MINERALS.

Following is a compilation of simple tests for the more common rocks and minerals (except iron) that the prospector may meet in the spar and metalliferous districts and elsewhere. The tests are presented in the hope that they may prove helpful not only to prospectors, but to the public generally. Many specimens are sent to the office of the State Geological Survey for determination that might readily be determined by the finder himself by the application of such tests as are here given. The tests have been compiled at the suggestion of the Director of the Survey.

FLUORSPAR.—Fluorspar may be readily distinguished from most of its associate Kentucky minerals. It is harder than, and hence will scratch, calcspar, but not as hard as glass, which quartz scratches readily. It does not possess the milky white color that calcite most frequently shows. It breaks into tetrahedral (similar to a three-sided pyramid, sometimes with the upper part cut off) and octahedral (eight sided) cleavages.

For different forms of fluorspar crystals and cleavages see the plate of transparent crystals in Chapter VI. Fluorspar does not effervesce or froth with acids as do calcspar and zinc carbonate. Fluorspar, powdered and placed in a glass tube or bottle together with concentrated sulphuric acid and heated, yields a coating near the mouth of the tube and etches the glass; care must be taken not to inhale or approach too closely the gas (hydrofluoric acid) which is given off, as it is exceedingly poisonous. None of the other minerals when heated with sulphuric acid etch glass. When heated on a shovel it flies apart (decrepitates) but all the other minerals do likewise. If heated to a white heat it emits a white phosphorescent light.

CALCSPAR (*Calcite*).—This is usually milky white in color, rarely gray or brownish. It froths readily if dilute hydrochloric acid be supplied; in fact, it is readily acted on by all

dilute acids. It is readily scratched with a piece of fluor-spar. It is not quite as heavy as fluorspar. If heated sufficiently long on a shovel it burns to quicklime. When crystallized it breaks into rhombohedral cleavages (a four-sided figure whose every side is a rhomboid). In caves it occurs in stalagmitic, stalactitic and encrusting forms, upon the floor, hanging from the roof and upon the sides, respectively. It also occurs in pointed crystals, white or brown (dog tooth spar), coating fluorspar and other minerals. It is found, too, both in needle-like (acicular) clusters and as thin fibrous plates.

LIMESTONE is simply an aggregate of irregular-shaped calcite grains. Sometimes it consists of rounded grains, like the roe of a fish, when it is called oolite. The tests for calcite apply also to most limestones. They will not serve in the case of a dolomite—a limestone containing a large proportion of magnesium carbonate—unless the acid and powder are heated.

BARITE, (barytes, heavy spar, or barium sulphate).—This is heavier than any of the minerals, save lead. It is usually white or slightly stained with iron. It is commonly fibrous and dull, sometimes pearly or vitreous when crystalline. A splinter moistened with hydrochloric acid colors a flame yellowish green. It does not dissolve or react with any of the cold acids. Strontianite and celestine are sometimes mistaken for barite. They are less heavy and give a crimson or yellow-red flame. Calcite also gives a red to yellow-red flame, but it is lighter than strontianite or celestine, and (among other ways) may be distinguished from them by the intense frothing when cold hydrochloric acid is applied.

QUARTZ.—This may be distinguished from the other spar-like minerals by being the only one sufficiently hard to scratch glass. It occurs in six-sided crystals, the sides coming to a point at one or both ends. It also occurs fibrous, when it often exhibits a fetid odor upon striking with a hammer.

SANDSTONE consists of an aggregate of irregularly worn quartz grains, while quartzite is simply hardened or more compact sandstone. Sandstone conglomerate is sandstone

containing more or less quartz pebbles. Chert is a fine grained variety of quartz, sometimes porous and again compact.

GYPSUM is sometimes mistaken for fluorspar. Gypsum occurs principally in shale or clay in little crystals which are soft and are easily cut with a knife. They may be separated with a knife into thin plates similar to isinglass, (mica), but, unlike isinglass, gypsum is brittle while isinglass is flexible. If put on a shovel and burnt, gypsum falls apart into thin leaf-like plates which become gray to white in color.

GALENA OR LEAD SULPHIDE.—This mineral is always of a lead-gray color and usually breaks into small cube-like plates. It is so soft it can be cut with a knife. Heated in a ladle sufficiently long it melts, giving off sulphur and leaving a lead bullet. It is twice as heavy as fluorspar and nearly twice as heavy as zinc.

SPALERITE, (zinc blende, jack, resin blende, zinc sulphide).—This mineral is usually yellowish-brown, reddish brown, or black in color. Its powder is of an orange color. It is slightly heavier than fluorspar, but not as heavy as barite. Small pointed crystals, red to brown in color, are rare. When freshly broken it has a luster similar to resin. It is harder than fluorspar. Heated on a shovel it gives off sulphur fumes. If heated with charcoal and sodium carbonate at a blacksmith's forge it produces a strong green flame. If heated with hydrochloric acid it gives off hydrogen sulphide gas which has the odor of rotten eggs.

SPHALERITE, (when in crystals in limestone, for instance), is sometimes mistaken for galena. If a crystal be scratched with the point of a knife blade, a white to reddish-brown streak will appear; which will not be the case with galena.

PYRITE, (iron pyrites, iron disulphide, fool's gold).—This mineral is often mistaken for gold, but is easily told from the latter. Gold is of a gold-yellow color usually, while pyrite has a pale brass-yellow color. Gold is very soft and can be cut usually with a knife, while pyrite is so hard a knife will not scratch it. Gold is about four times as heavy as pyrite. Powdered pyrite is greenish black to brown-black, while powdered gold is always gold yellow. Heated on a shovel, pyrite

gives off sulphur fumes, gold does not. Pyrite may be dissolved in nitric acid, gold cannot be. Copper pyrites or (chalcopyrite), occasionally found in this State, is a darker brass color than pyrite. It can be scratched easily with a knife, being about as hard as fluorspar. It is about as heavy as pyrite. It may readily be told from pyrite or gold by dissolving it in nitric acid, when it forms a green solution, which upon the addition of an excess of ammonia changes to blue color, and a red powder falls to the bottom of the glass.

EARTHY MANGANESE.—Cobalt Ore.—This has a bluish-black, sometimes reddish or brownish black color, and occurs in clay or shales in small veins or pockets, usually near larger veins or faults. Selected samples contain sometimes 10 or more per cent. of manganese and from a trace to as high as 3 per cent. of cobalt-nickel. Usually, it is soft and earthy, rarely hard and crystalline. A little fragment heated with borax will color the borax purple. This shows there is some manganese present, but tells nothing about cobalt or nickel as the amounts of these are usually so small as to require careful analysis by a chemist to determine their presence. Analyses of samples that were collected in the Western Kentucky mineral district are given in Appendix I.

APPENDIX III.

U. S. CENSUS TABLE.

The appended tables are from the special report on Mines and Quarries, 1902, of the U. S. Census Bureau. Table A. compares the status of the industry in 1902 and 1889. The figures given for 1902 are incorrect in two particulars; (1) the amount of contract work in 1902 far exceeded the amount reported by the Census and (2) the amount mined was less by several thousand tons than that reported. (For correct statistics see Chapter I. of this Bulletin).

The writer was unable to collect satisfactory returns as to the number of men employed, etc., for comparison of the industry in 1906 with that in 1902, owing to fragmentary

character of the work of many of the mining companies, working only parts of the year, employing an irregular number of men, working the several mines at different times. etc. There was, however, a substantial advancement in the industry in 1906 over 1902. The number of mines producing fluorspar in 1906 was fully twice that in 1902. The number of wage earners engaged in fluorspar mining and milling probably exceeded 500, which was over 200 more than in 1902.

Table B. gives the capitalization of the incorporated companies connected with the industry in 1902. In 1906, the number of individuals, corporations and firms actively engaged in the industry in Illinois was 10; in Kentucky 35 with two additional engaged in milling; in other States, Colorado and Tennessee, 3, a total of 48.

The last table, Table C., gives a detailed summary of the condition of the industry in 1902.

TABLE A
STATUS OF FLOURSPAR INDUSTRY, 1889 AND 1902.

	1902	1889
Number of mines -----	22	†
Number of operators -----	18	†
Salaried officials, Clerks, etc.;		
Number -----	42	†
Salaries -----	\$ 27,311	†
Wage-earners		
Average number -----	269	101
Wages -----	\$110,002	\$14,213
Contract work -----	\$ 300	†
Miscellaneous expenses -----	\$ 23,602	\$ 3,008
Cost of supplies and material -----	\$ 31,374	\$ 5,025
Product: †		
Quantity, short tons -----	48,818	9,500
Value -----	\$275,682	\$45,855

† Not reported.

†The United States Geological Survey reports 48,018 short tons for 1902, valued at \$271,832, which is the product marketed. Census figures represent the product mined.

TABLE B
CAPITALIZATION OF INCORPORATED COMPANIES, 1902.

	United States	Illinois	Kentucky	All other States †
Number of incorporated companies -	14	3	9	2
Capital stock and bonds issued-----	\$2,214,000	\$1,536,000	\$628,000	\$50,000
Capital Stock (all common):				
Total authorized—				
Number of shares-----	3,146,730	2,500,000	606,630	40,100
Par value -----	\$3,813,000	\$2,500,000	\$1,263,000	\$50,000
Total issued—				
Number of shares -----	1,726,320	1,536,000	150,220	40,100
Par value -----	\$2,154,000	\$1,536,000	\$538,000	\$50,000
Bonds: -----				
Authorized—				
Number -----	1,000	-----	1,000	-----
Par value -----	\$ 100,000	-----	\$ 100,000	-----
Issued—				
Number -----	600	-----	600	-----
Par value -----	\$ 60,000	-----	\$ 60,000	-----

† Includes companies distributed as follows:
Arizona 1; Tennessee, 1.

TABLE C
DETAILED SUMMARY, 1902.

	United States	Illinois	Kentucky	All other States and Territories (†)
Number of mines-----	22	5	14	3
Number of operators-----	18	5	10	3
Character of ownership—				
Individual-----	2	1	-----	1
Firm-----	2	1	1	-----
Incorporated company-----	14	3	9	2
Salaried official clerks, etc—				
Total number-----	42	9	31	2
Total salaries-----	\$ 27,311	\$ 5,304	\$21,107	\$ 900
General officers—				
Number-----	12	1	11	-----
Salaries-----	\$ 11,545	\$ 300	\$11,245	-----
Superintendents, managers, foremen, surveyors, etc.—				
Number-----	17	3	12	2
Salaries-----	\$ 12,437	\$ 3,500	\$ 8,037	\$ 900
Foremen below ground—				
Number-----	11	3	8	-----
Salaries-----	\$ 2,849	\$ 1,024	\$ 1,825	-----
Clerks—				
Number-----	2	2	-----	-----
Salaries-----	\$ 480	\$ 480	-----	-----
Wage-earners—				
Aggregate average number-----	269	71	193	5
Aggregate wages-----	\$110,002	\$28,845	\$79,107	\$2,050
Above ground—				
Total average number-----	140	38	98	4
Total wages-----	\$ 56,235	\$15,328	\$39,407	\$1,500
Engineers, firemen and other mechanics—				
Average number-----	25	5	20	-----
Wages-----	\$ 12,626	\$ 2,481	\$10,145	-----
Miners—				
Average number-----	56	4	48	4
Wages-----	\$ 21,180	\$ 1,275	\$18,405	\$1,500
Boys under 16 years—				
Average number-----	2	-----	2	-----
Wages-----	\$ 234	-----	\$ 234	-----
All other wage earners—				
Average number-----	57	29	28	-----
Wages-----	\$ 22,195	\$11,572	\$10,623	-----
Below ground—				
Total average number-----	129	33	95	1
Total wages-----	\$ 53,767	\$13,517	\$39,700	\$ 550

†Includes Companies distributed as follows :
Arizona 1 ; Tennessee, 1.

TABLE C—Continued.
DETAILED SUMMARY, 1902.

	United States	Illinois	Kentucky	All other States and Territories (†)
Below ground—Continued				
Miners				
Average number.....	120	24	95	1
Wages	\$ 50,504	\$10,254	\$39,700	\$ 550
Miners' helpers—				
Average number.....	9	9	-----	-----
Wages	\$ 3,263	\$ 3,263	-----	-----
Average number of wage earners at specified daily rates of pay—				
Engineers—				
\$1.50 to \$1.74.....	14	2	12	-----
\$2.50 to \$2.74.....	2	1	1	-----
Firemen—				
\$1.00 to \$1.24.....	1	-----	1	-----
\$1.25 to \$1.49.....	1	1	-----	-----
\$2.00 to \$2.24.....	2	-----	2	-----
Machinists, blacksmiths and carpenters and other me- chanics—				
\$1.50 to \$1.74.....	2	1	1	-----
\$2.50 to \$2.74.....	1	-----	1	-----
\$3.00 to \$3.24.....	2	-----	2	-----
Miners—				
\$1.00 to \$1.24.....	35	5	28	2
\$1.25 to \$1.49.....	100	12	88	-----
\$1.50 to \$1.74.....	32	7	25	-----
\$1.75 to \$1.99.....	5	1	2	2
\$2.00 to \$2.24.....	4	3	-----	1
Miners' helpers				
\$1.00 to \$1.24.....	1	1	-----	-----
\$1.25 to \$1.49.....	8	8	-----	-----
Boys under 16 years—				
\$0.75 to \$0.99.....	2	-----	2	-----
All other wage earners—				
\$1.00 to \$1.24.....	2	1	1	-----
\$1.25 to \$1.49.....	45	25	20	-----
\$1.50 to \$1.74.....	3	-----	3	-----
\$2.00 to \$2.24.....	7	3	4	-----

† Includes Companies distributed as follows:
Arizona, 1; Tennessee, 1.

TABLE XVIII—Continued.
DETAILED SUMMARY, 1902.

	United States	Illinois	Kentucky	All other States and Territories (†)
Average number of wage earners employed during each month, Men 16 years old and over—				
January	161	58	103	-----
February	147	51	96	-----
March	147	49	98	-----
April	183	60	123	-----
May	255	66	186	3
June	280	67	210	3
July	333	88	243	2
August	340	89	243	8
September	354	85	259	10
October	375	83	286	12
November	336	76	249	11
December	293	80	202	11
Boys under 16 years—				
July	4	-----	4	-----
August	4	-----	4	-----
September	4	-----	4	-----
October	4	-----	4	-----
November	4	-----	4	-----
December	4	-----	4	-----
Contract work—				
Amount paid	\$ 300	-----	\$ 300	-----
Number of employees	3	-----	3	-----
Miscellaneous expenses				
Total	\$ 23,602	\$ 1,149	\$22,328	\$ 125
Royalties and rent of mine and mining plant				
7,900	200	7,650	-----	
Rent of offices, taxes, insurance, interest and other sundries				
15,702	899	14,678	125	
Cost of supplies and materials				
31,374	17,115	13,925	307	
Product—				
Quantity, short ton	48,818	18,860	29,030	928
Value	\$275,682	\$123,000	\$143,410	\$9,272
Power owned—				
Total horse power	669	162	507	-----
Engines, Steam—				
Number	17	6	11	-----
Horse power	530	162	363	-----
Gas or gasoline—				
Number	10	-----	10	-----
Horse power	139	-----	139	-----
Electric Motors—				
Number	1	-----	1	-----
Horse power	25	-----	25	-----

†Includes Companies distributed as follows:
Arizona, 1; Tennessee, 1.

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